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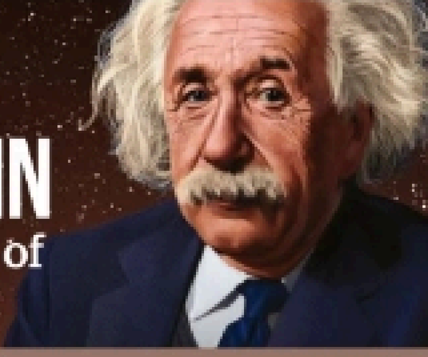

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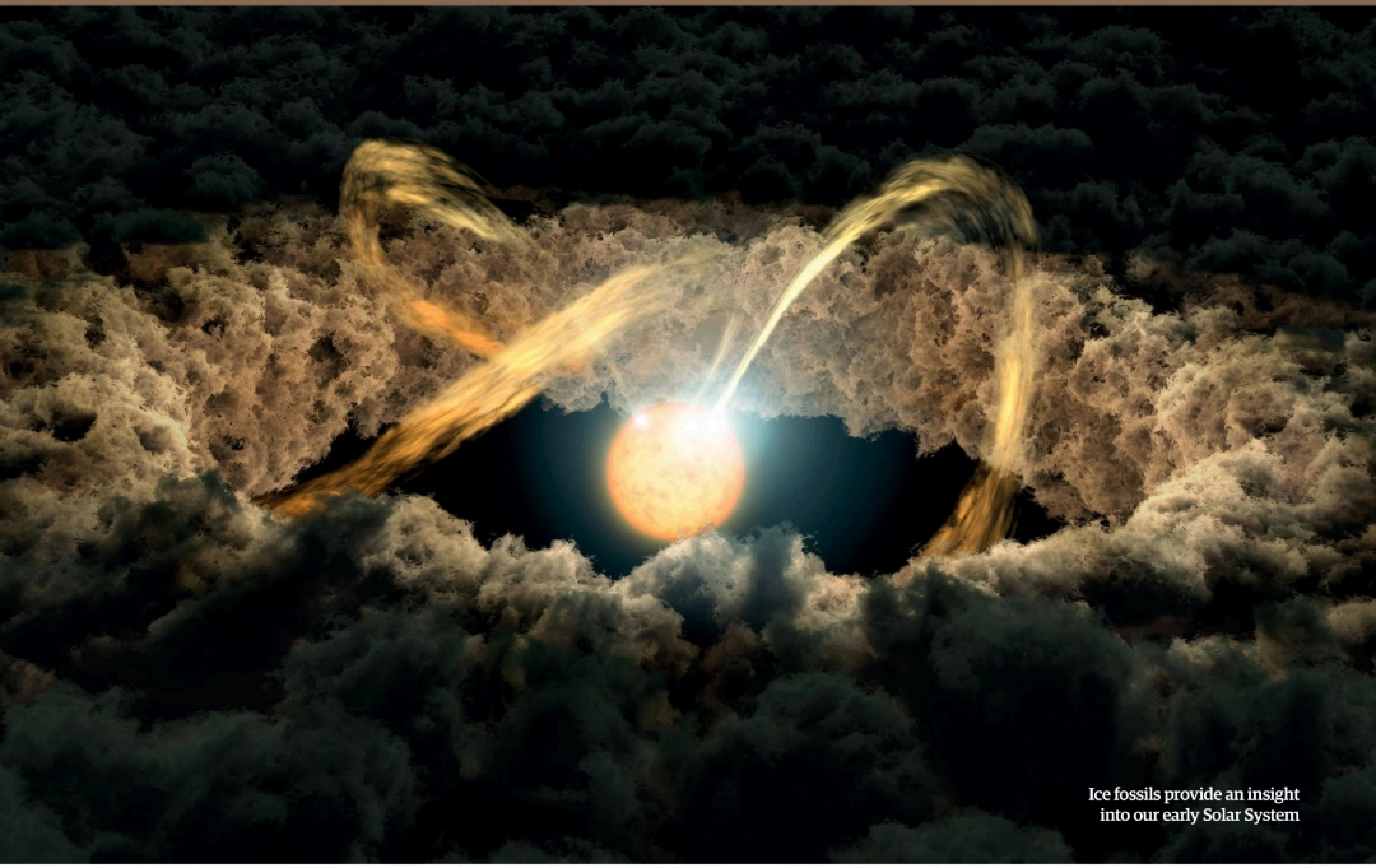

Ice fossils provide an insight into our early Solar System

Welcome

We're returning to Pluto – and this time we're looking to stay. That's the latest news from NASA as it looks to develop the very first spacecraft that's set to park itself into a loop around the dwarf planet, sometime beyond the 2020s.

It comes after the success of New Horizons, which hurtled past Pluto at a speed of 58,500 kilometres (36,400 miles) per hour while busily snapping away, revealing one side of the dwarf planet like never before.

On 14 July 2015 the astronomical community truly had the dwarf planet in its crosshairs. We're now intent on a return that'll make its terrain as familiar as that of Mars, the only other planet in the Solar System – bar Earth – that's swarming with spacecraft. Of course, we know how to get to Pluto – but what'll be involved in swinging into orbit? New Horizons principal investigator Alan Stern reveals a lot of propellant is needed to afford us the opportunity to study the planet's moons, atmosphere, solar wind interactions and other aspects of the planetary system up close. Turn to page 16 for a full overview of the Pluto Orbiter.

We're well into the darker evenings, with many of us dusting off our telescopes to spend the majority of our waking hours under the stars. From astronomer Stuart Atkinson's planet, moon, naked-eye and deep-sky tours to Mark Thompson's advice on solving your kit woes, we've got everything you need to make the most of your hobby.

Gemma Lavender
Editor-in-Chief

Our contributors include...

Colin Stuart
Space science writer
Colin reveals everything you need to know about chaos theory and how it influences the workings of the universe, the Earth and everyday life.

Lee Cavendish
Staff Writer
Your ride into space starts here! Join Lee as he travels the world to reveal future spaceports, the craft you'll be taking off in and what you'll experience.

Chris Lintott
Astrophysicist
Want to get involved in scientific research? Chris reveals how you don't need a qualification in space science to play an important part with citizen science.

Mark Thompson
Astronomer
What's wrong with my telescope? Mark takes our reader's queries on how to resolve the biggest observing woes to get you back up and running again.

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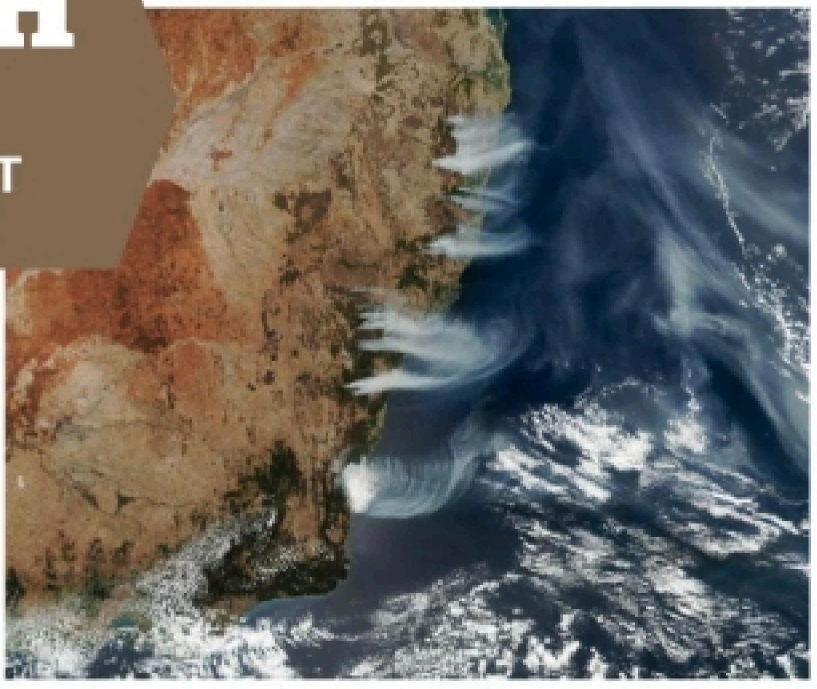

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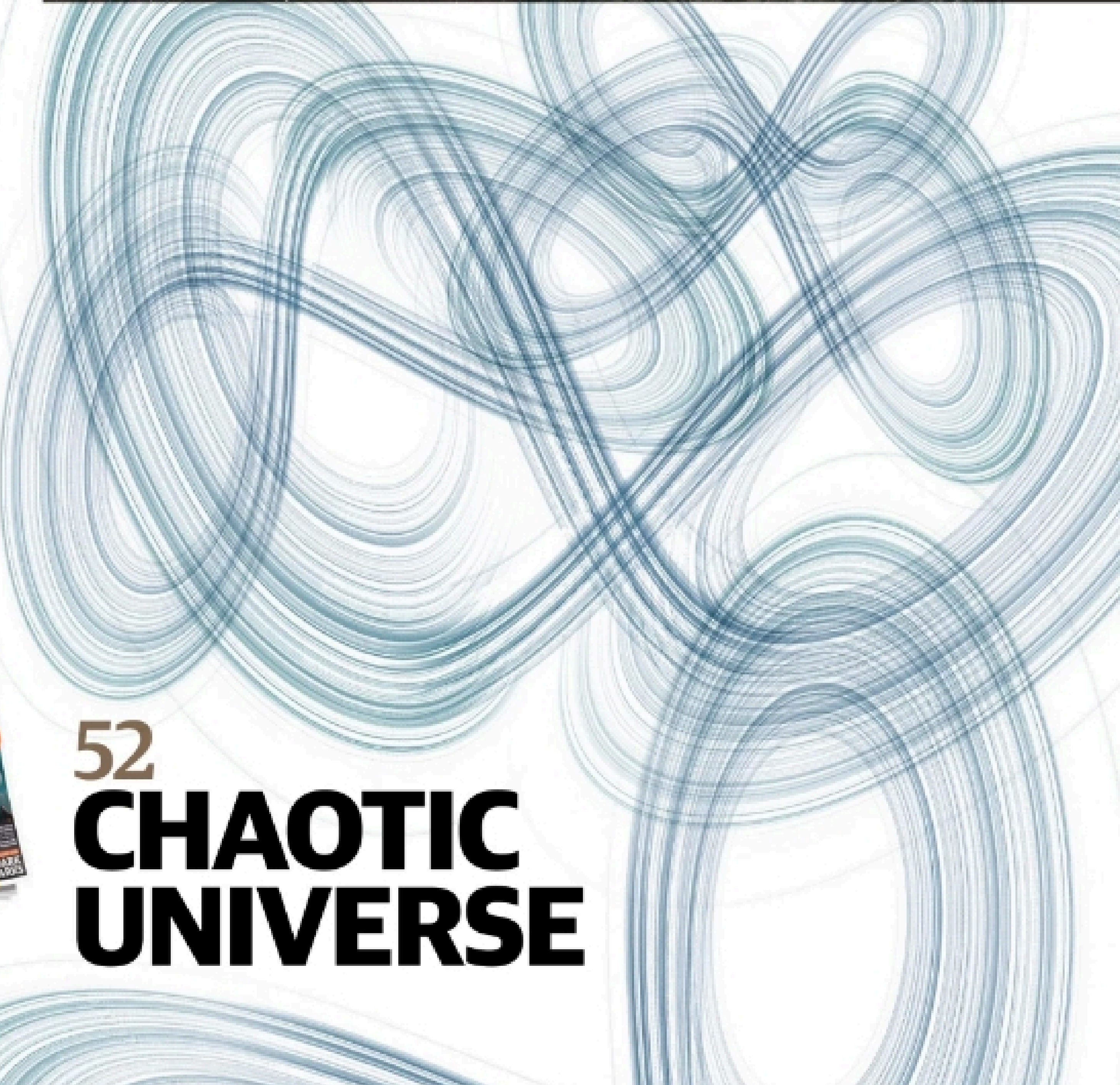

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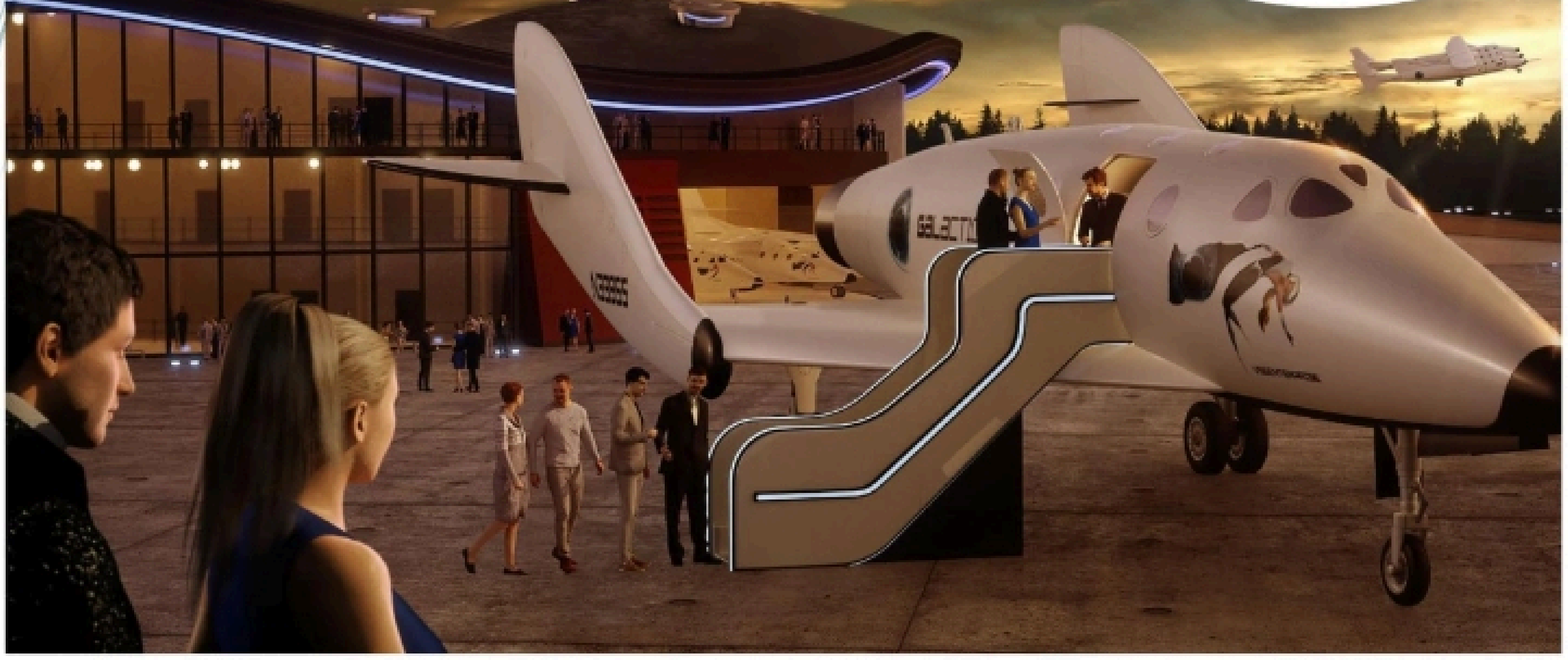

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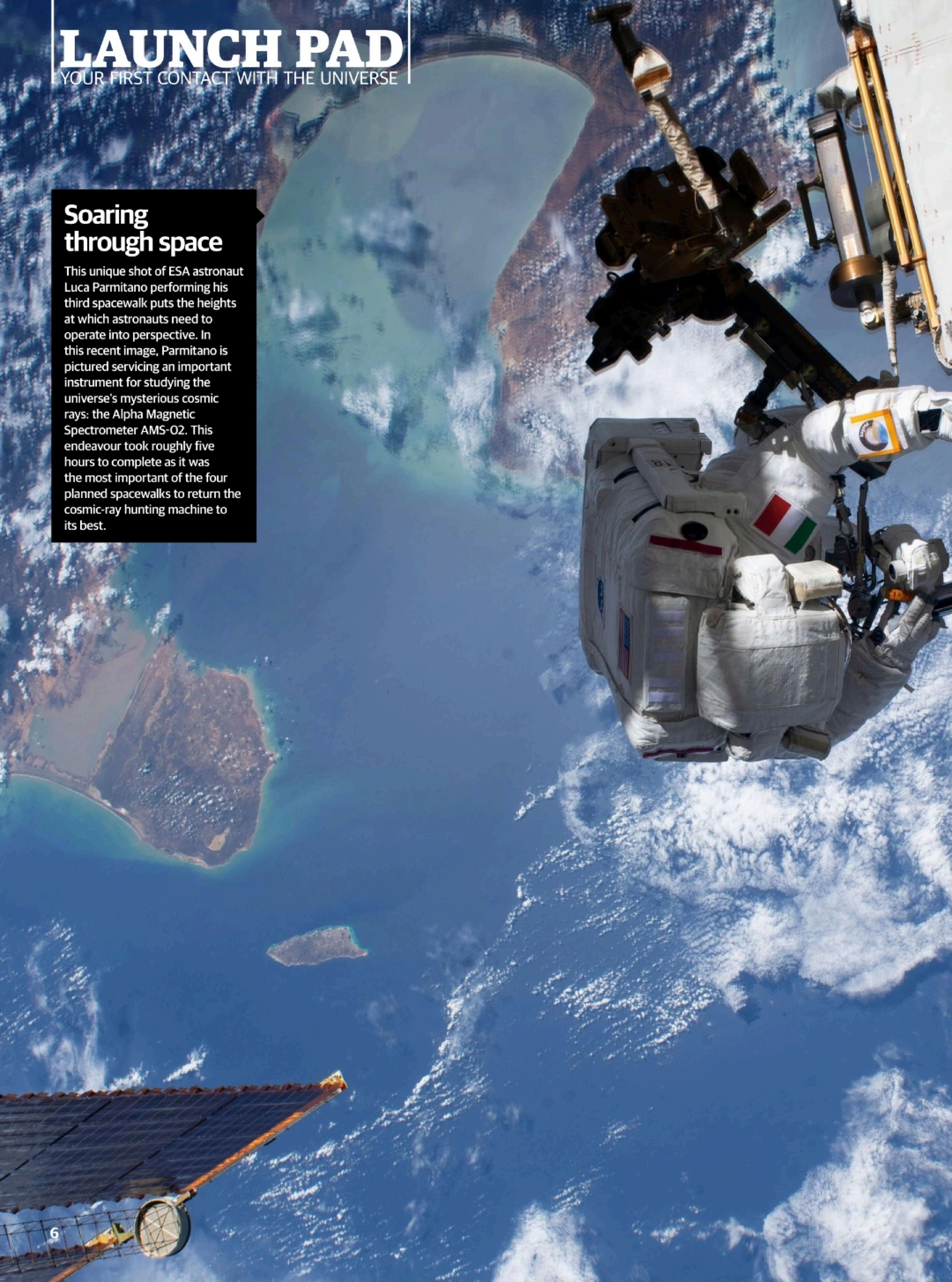

Soaring through space

This unique shot of ESA astronaut Luca Parmitano performing his third spacewalk puts the heights at which astronauts need to operate into perspective. In this recent image, Parmitano is pictured servicing an important instrument for studying the universe's mysterious cosmic rays: the Alpha Magnetic Spectrometer AMS-02. This endeavour took roughly five hours to complete as it was the most important of the four planned spacewalks to return the cosmic-ray hunting machine to its best.

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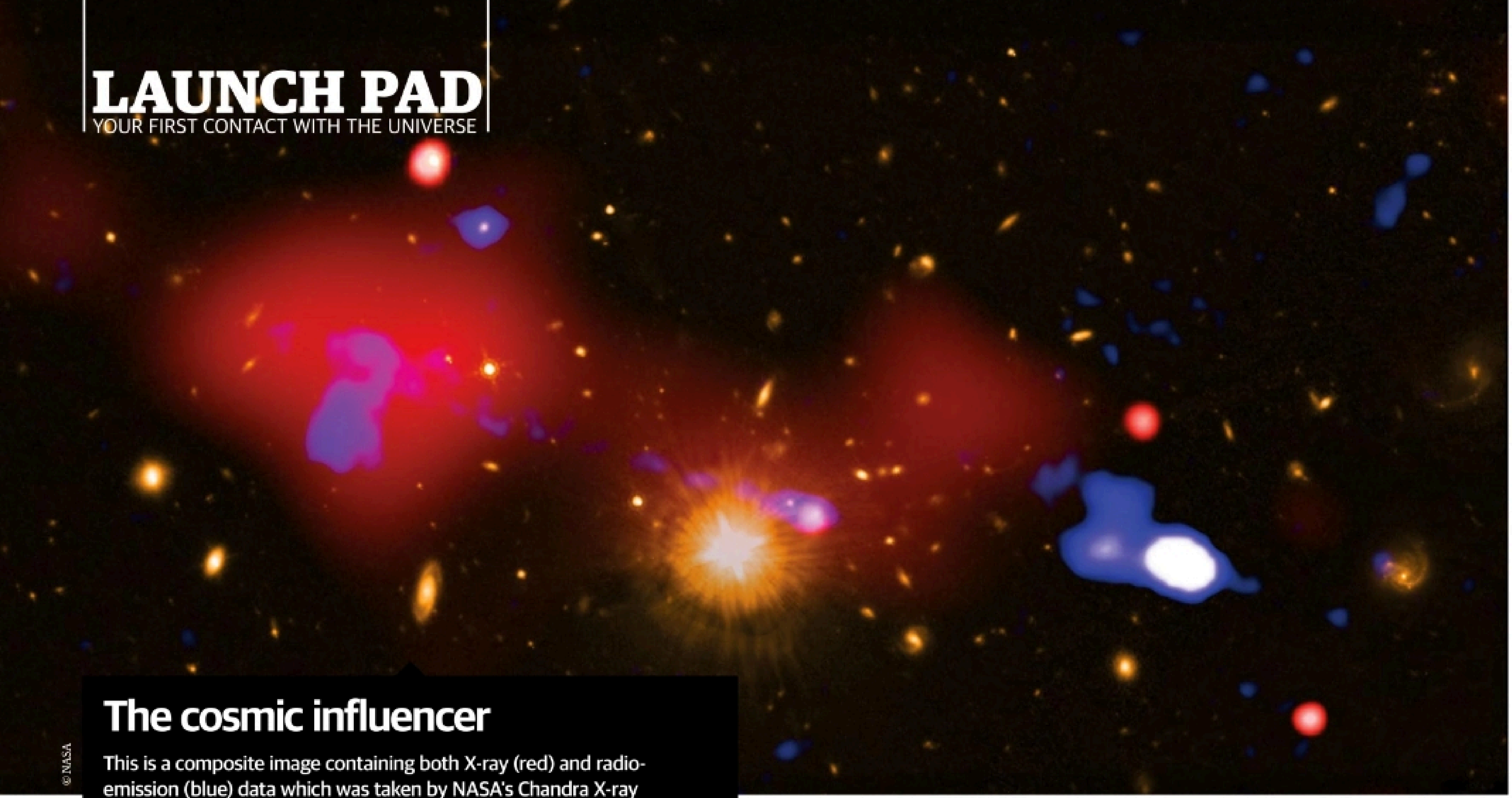

The cosmic influencer

This is a composite image containing both X-ray (red) and radio-emission (blue) data which was taken by NASA's Chandra X-ray Observatory and the National Science Foundation's Karl Jansky Very Large Array (VLA) in New Mexico. Together they provide vital evidence that there is a black hole at the centre of a galaxy 9.9 billion light years away which is kick-starting star formation in at least four neighbouring galaxies.

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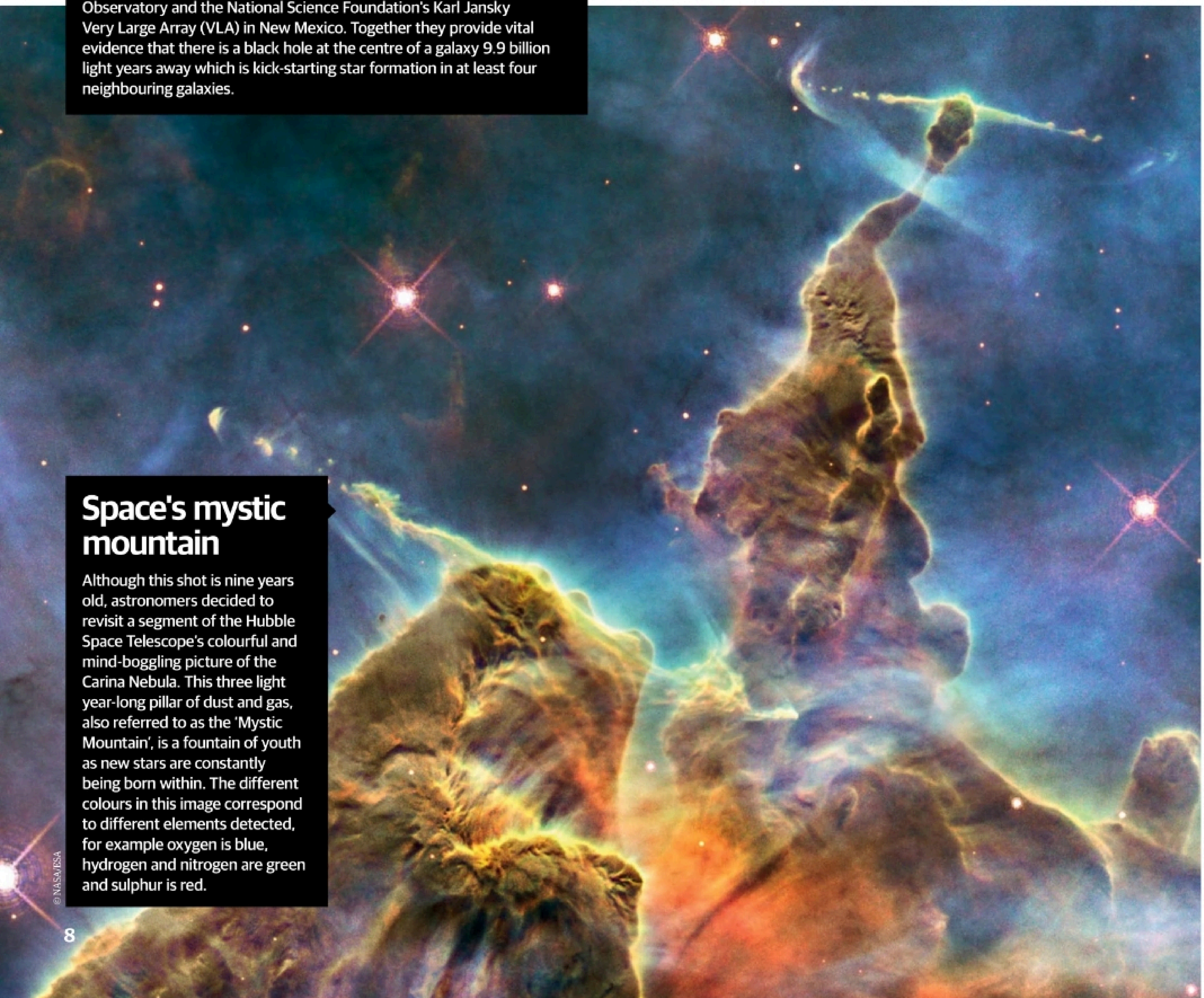

Space's mystic mountain

Although this shot is nine years old, astronomers decided to revisit a segment of the Hubble Space Telescope's colourful and mind-boggling picture of the Carina Nebula. This three light year-long pillar of dust and gas, also referred to as the 'Mystic Mountain', is a fountain of youth as new stars are constantly being born within. The different colours in this image correspond to different elements detected, for example oxygen is blue, hydrogen and nitrogen are green and sulphur is red.

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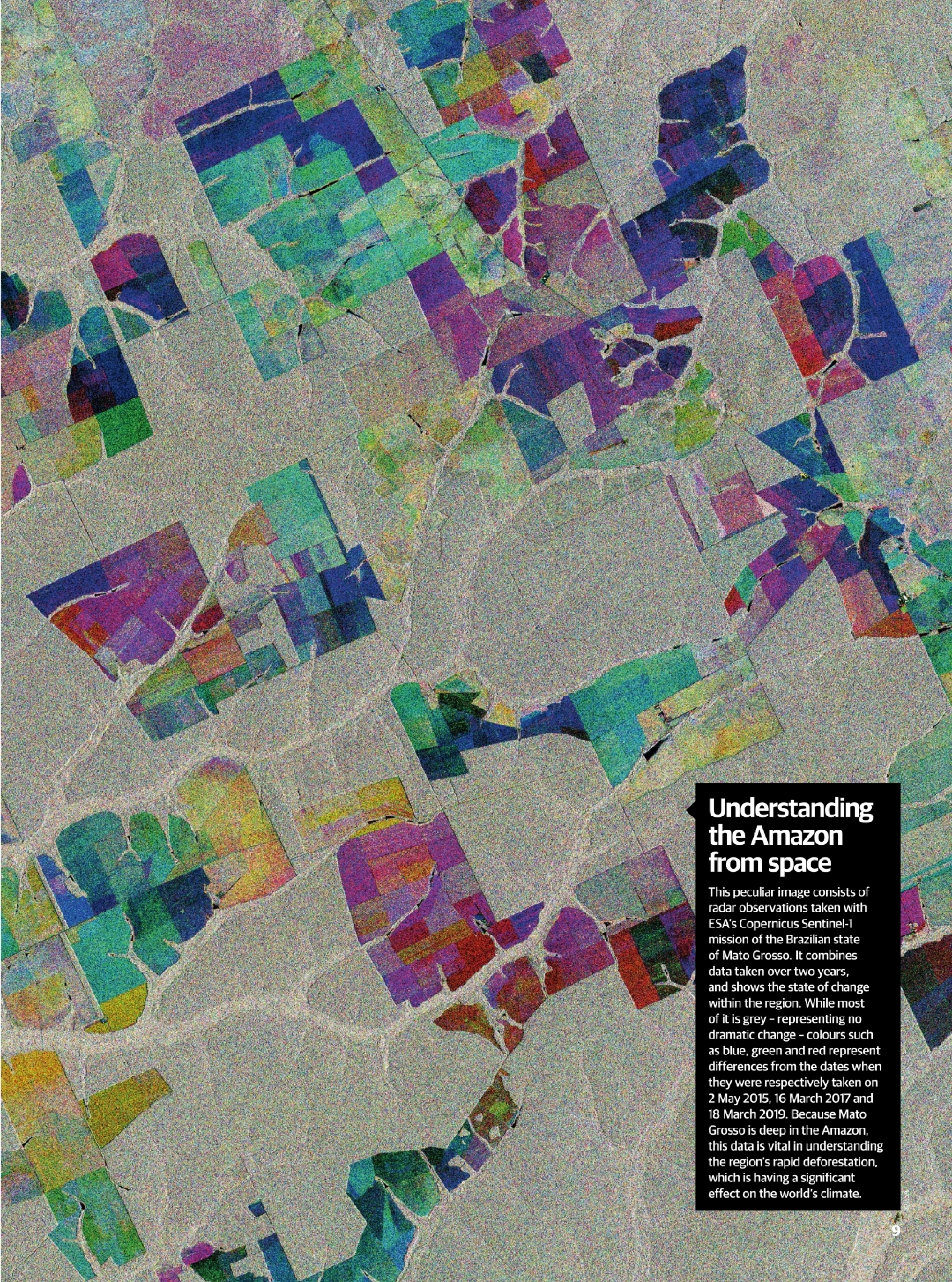
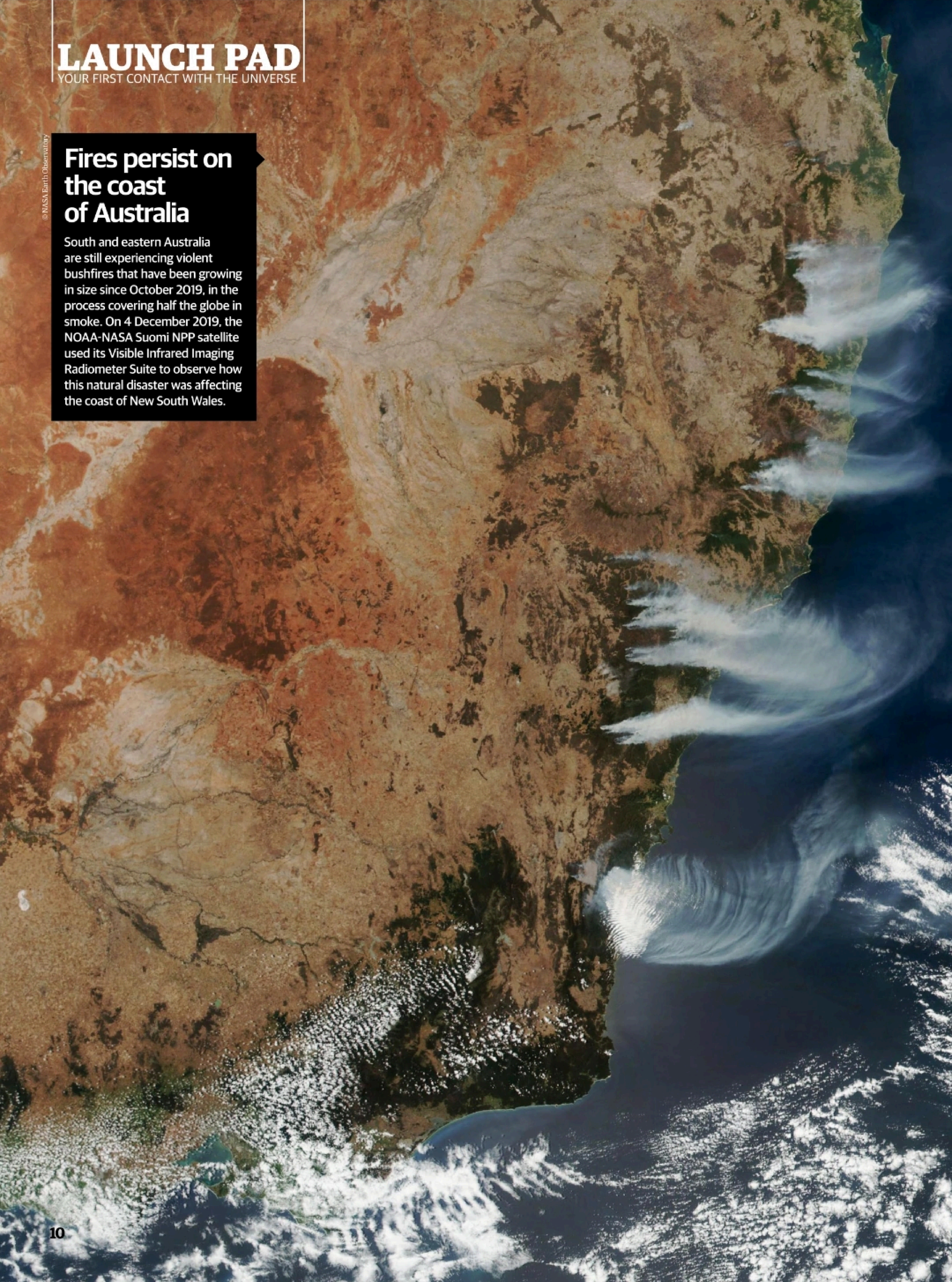


Understanding the Amazon from space

This peculiar image consists of radar observations taken with ESA's Copernicus Sentinel-1 mission of the Brazilian state of Mato Grosso. It combines data taken over two years, and shows the state of change within the region. While most of it is grey – representing no dramatic change – colours such as blue, green and red represent differences from the dates when they were respectively taken on 2 May 2015, 16 March 2017 and 18 March 2019. Because Mato Grosso is deep in the Amazon, this data is vital in understanding the region's rapid deforestation, which is having a significant effect on the world's climate.

Fires persist on the coast of Australia

South and eastern Australia are still experiencing violent bushfires that have been growing in size since October 2019, in the process covering half the globe in smoke. On 4 December 2019, the NOAA-NASA Suomi NPP satellite used its Visible Infrared Imaging Radiometer Suite to observe how this natural disaster was affecting the coast of New South Wales.



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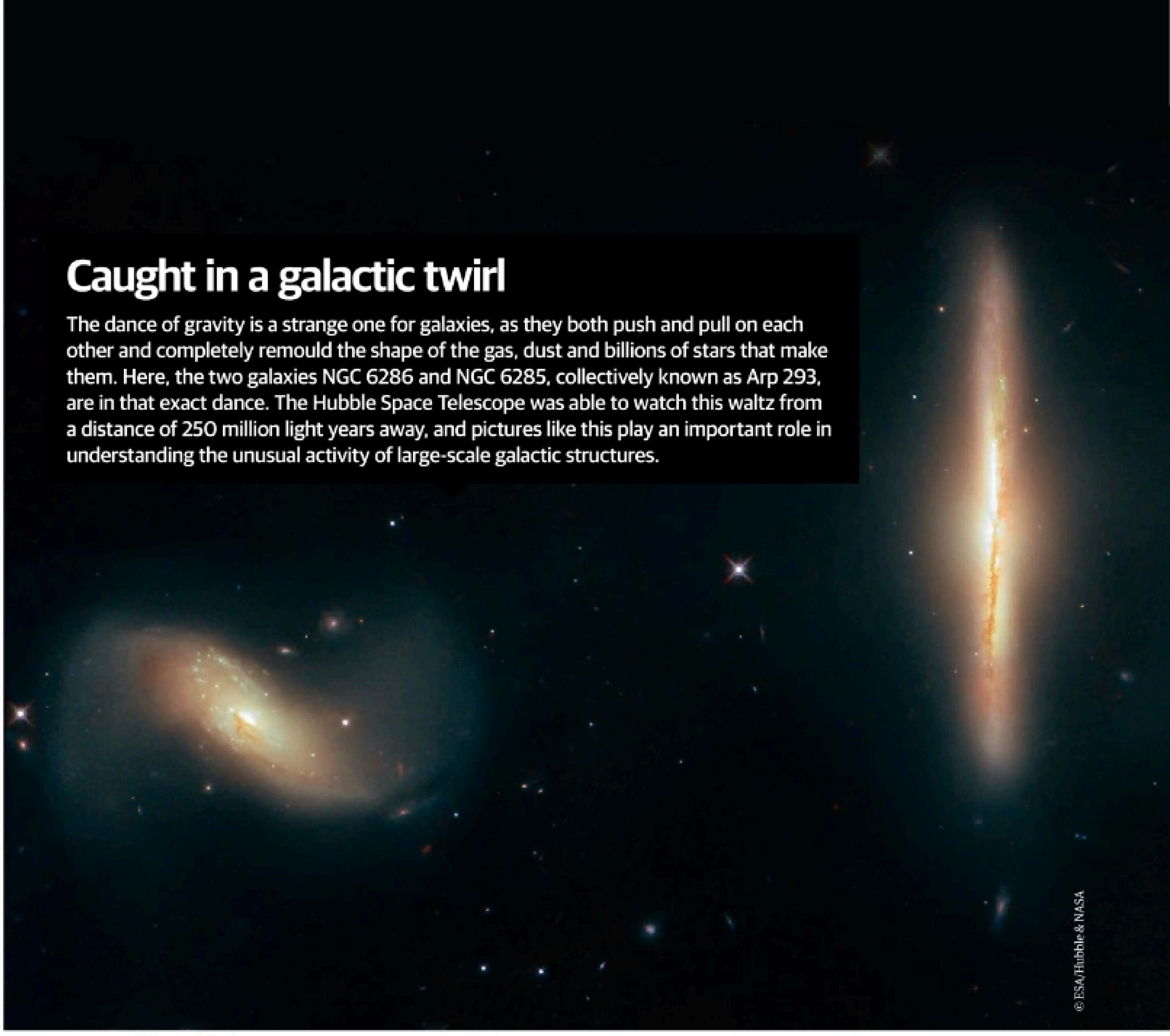

Caught in a galactic twirl

The dance of gravity is a strange one for galaxies, as they both push and pull on each other and completely remould the shape of the gas, dust and billions of stars that make them. Here, the two galaxies NGC 6286 and NGC 6285, collectively known as Arp 293, are in that exact dance. The Hubble Space Telescope was able to watch this waltz from a distance of 250 million light years away, and pictures like this play an important role in understanding the unusual activity of large-scale galactic structures.

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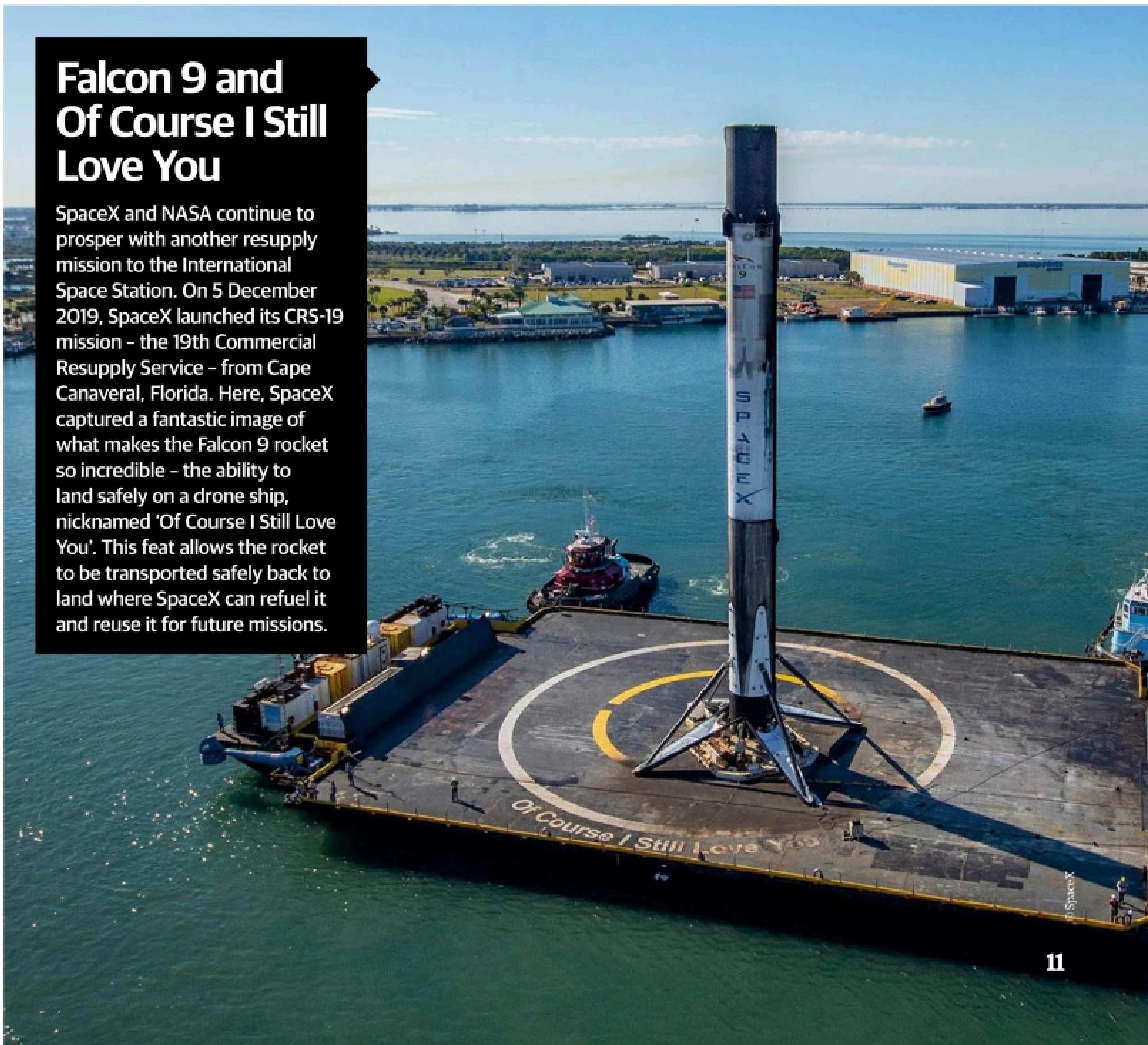


Falcon 9 and Of Course I Still Love You

SpaceX and NASA continue to prosper with another resupply mission to the International Space Station. On 5 December 2019, SpaceX launched its CRS-19 mission – the 19th Commercial Resupply Service – from Cape Canaveral, Florida. Here, SpaceX captured a fantastic image of what makes the Falcon 9 rocket so incredible – the ability to land safely on a drone ship, nicknamed 'Of Course I Still Love You'. This feat allows the rocket to be transported safely back to land where SpaceX can refuel it and reuse it for future missions.

© SpaceX

Alien planet spotted around a white dwarf – a cosmic first

Words by Mike Wall

For the first time ever, astronomers have spotted evidence of an exoplanet circling a superdense stellar corpse known as a white dwarf, a new study reports. The vast majority of stars in the Milky Way galaxy, including our own Sun, will end up as white dwarfs. When these stars finish burning their nuclear fuel, they'll first bloat up as enormous red giants, then eventually collapse down into white dwarfs, which pack about one solar mass into a sphere the size of Earth.

Lead scientist Boris Gaensicke from the University of Warwick and his colleagues studied a white dwarf called WDJ0914+1914, which lies about 2,040 light years from Earth. In data gathered by the Sloan Digital Sky Survey, the researchers detected emissions of hydrogen, sulphur and oxygen coming from WDJ0914+1914.

That's an odd combination of gases for a white-dwarf system, so the team trained the European Southern Observatory's Very Large Telescope (VLT) in Chile on WDJ0914+1914. The VLT observations confirmed the presence of all three elements, and suggested that the emissions are coming from a ring of gas around the white dwarf.

"At first we thought that this was a binary star with an accretion disc formed from mass flowing between the two stars," Gaensicke said. "However, our observations show that it is a single white dwarf with a disc around it roughly ten times the size of our Sun made solely of hydrogen, oxygen and sulphur. Such a system has never been seen before, and it was immediately clear to me that this was a unique star."

The composition of this disc is similar to that of our Solar System's ice giants, Neptune and Uranus, the researchers said. It seems that a Neptune-like world – one about four-times wider than WDJ0914+1914 itself – is circling the white dwarf once every ten Earth days.

But this planet's days appear to be numbered. Calculations performed by the team indicate that the white dwarf, which has a surface temperature around 28,000 degrees Celsius (50,400 degrees Fahrenheit), is evaporating the alien Neptune at a prodigious rate – about 3,300 tonnes (3,640 imperial tons) per second.

Above: The unique planet is slowing being deteriorated by its dead host

Right: An accidental bubble discovery may unlock some of Titan's mysteries

> "Such a system has never been seen before, and it was clear that this was a unique star" **Boris Gaensicke**

© NASA

Weird physics of Enceladus' 'tiger stripes' explained

Words by Chelsea Gohd

New research solves some of the mysteries of the 'tiger stripes' on Saturn's moon Enceladus. The moon has been of particular interest to scientists ever since it was observed in detail by NASA's Cassini spacecraft. With Cassini's data, scientists detected an icy subsurface ocean on the moon and strange tiger-stripe markings on the moon's south pole that are unlike anything else in the Solar System. Icy material from Enceladus' ocean spews into space through these stripes, or fissures, in the moon's surface.

"First seen by the Cassini mission to Saturn, these stripes are like nothing else known in our Solar System," lead scientist Doug Hemingway said in an statement. "They are parallel and evenly spaced, about 130 kilometres [80.7 miles] long and 35 kilometres [21.7 miles] apart. What makes them especially interesting is that they are continually erupting with water ice, even as we speak. No other icy planets or moons have anything quite like them."

Right: The tiger stripes were one of Cassini's many unusual finds as it orbited Saturn

© NASA/ESA

The moon isn't frozen solid, as gravitational changes caused by its eccentric orbit around Saturn stretch it out slightly. This deformed shape causes the ice sheets at the poles to be thinner and more susceptible to splitting open, the researchers found. This led them to conclude that the fissures that make up these tiger stripes could have formed on the moon's north pole just as well as the south pole, but the south pole just cracked first.

Lakes may bubble up into 'magic islands' on Saturn's Titan

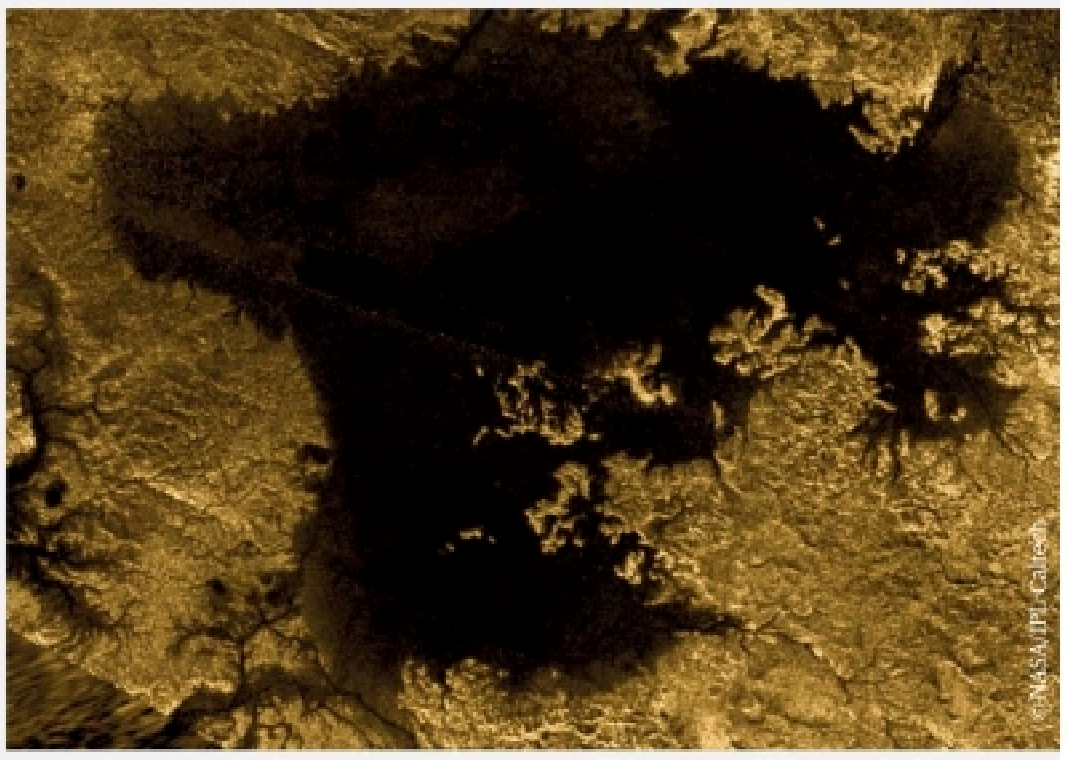
Words by Meghan Bartels

Champagne is supposed to be bubbly. So is a foaming bath. But a mixture designed to mimic the frigid lakes on an alien moon? That's a little more surprising. Especially when those bubbles come out of nowhere and explode. But that's what Kendra Farnsworth and her colleagues found during a set of experiments designed to help the team understand how compounds like those found on Titan interact. The accidental bubble discovery could help explain one of the mysteries spotted by NASA's Cassini mission – 'magic islands', bright patches on radar images that suddenly disappeared.

"At the beginning, it wasn't the main goal of the study, but it was one of those really surprising results," Farnsworth, a doctoral student in planetary science at the University of Arkansas, said. "Bubbles had been predicted on Titan, but nobody had actually seen them or created them in a laboratory."

In the experiment where the bubbles first appeared, Farnsworth had set out to measure how much nitrogen gas would dissolve in different mixtures of liquid methane and ethane, the organic compounds that make up Titan's strangely Earth-like system of rainfall, lakes and seas. As she warmed up these ponds, Farnsworth noticed small bubbles would snake to the surface. But the real surprise came in a different experiment, Farnsworth said, one based on slowly adding liquid ethane into liquid methane at Titan's surface temperature.

Particularly interesting was the slightly warmer scenario meant to mimic modern Titan. In these experiments, the team found, two factors had to change simultaneously: the temperature of the liquid and the relative proportion of methane and ethane. The combination of changes takes the mixture from stillness to a spurt of bubbles. "There's nothing and they explode," Farnsworth said. "They're more violent than we ever expected."



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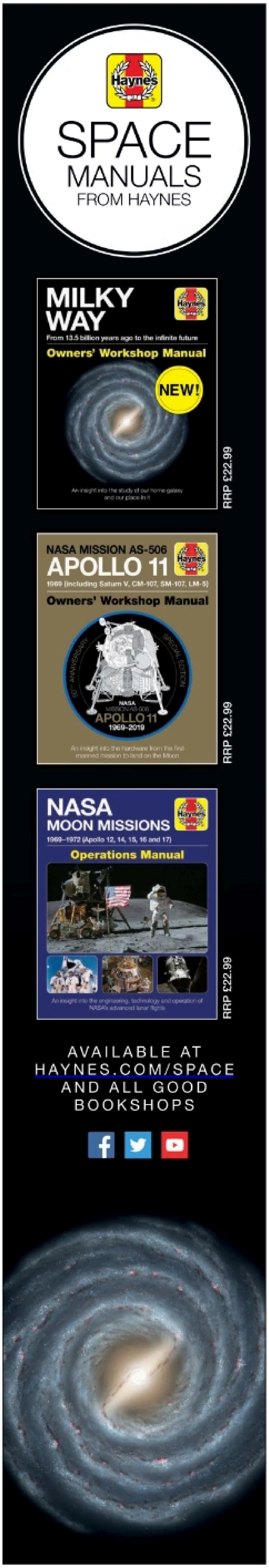

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Eruptions on asteroid Bennu hint at causes of space rock explosions

Words by Charles Q Choi

For the first time, astronomers have gotten an up-close view of eruptions from an asteroid, shedding light on what might drive such explosions. The findings suggest that many asteroids may be similarly active and reveal that rocks blasting off asteroids may be a new way for meteorites to reach Earth, the scientists wrote in a new study.

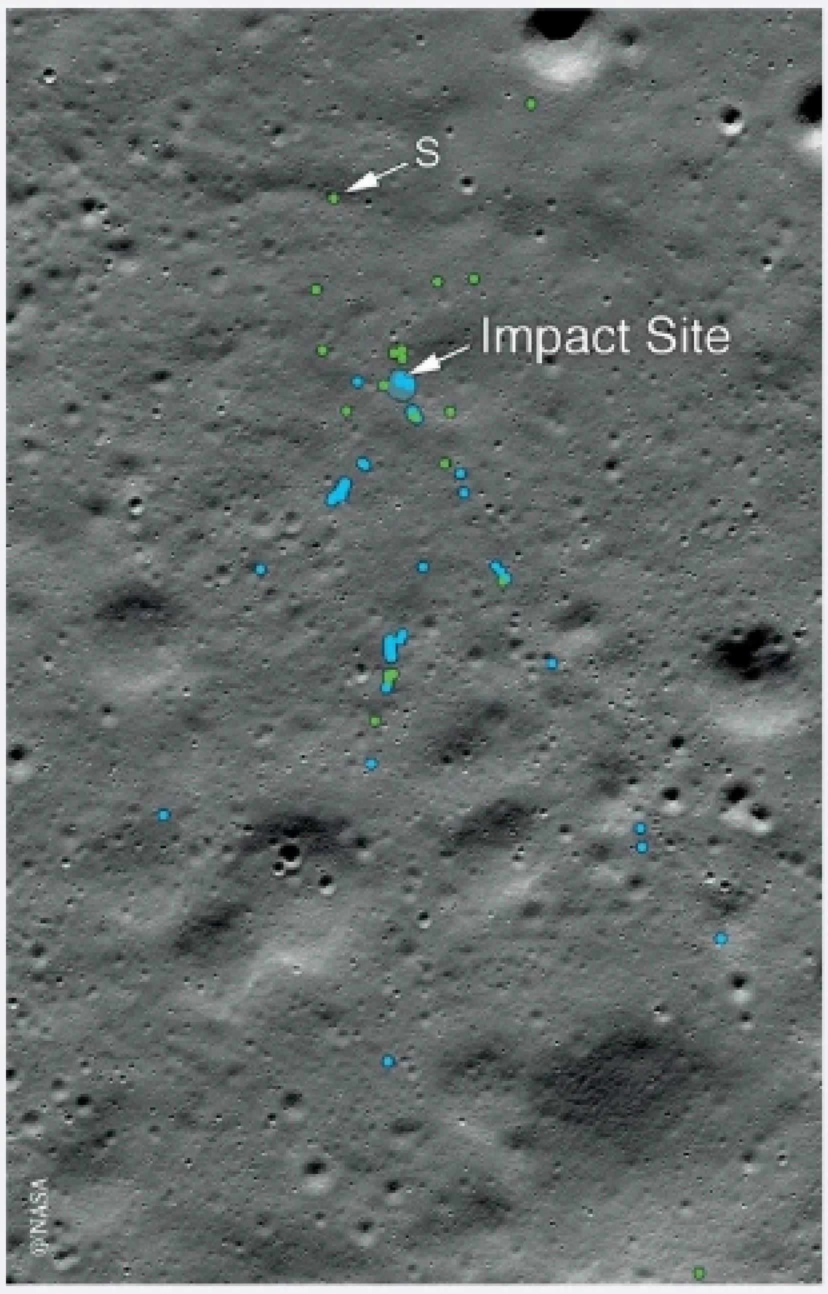
Previous research found that a small number of asteroids could actively erupt with large amounts of dust and bits of rock. Much remains unknown about what drives such outbursts in active asteroids. Now, scientists have captured images of eruptions from the near-Earth asteroid Bennu. "This is the first view of an active asteroid this close up," Harold Connolly, a sample scientist for the OSIRIS-REx mission, told space.com. Scientists chose to send OSIRIS-REx to Bennu because the space rock looks similar to known active asteroids. But they hadn't seen any eruptions from Bennu until now.

The researchers spotted three large eruptions from Bennu in January and February of this year, each ejecting a maximum of 200 chunks up to ten-centimetres (four-inches) across at top speeds of about 11.9 kilometres (7.4 miles) per hour. They also detected eight smaller eruptions that ejected about 20 or fewer bits of asteroid.

The scientists also discovered six chunks of rock around Bennu that they suggested were ejected during eruptions and stayed gravitationally bound to the asteroid. Some ultimately escaped into interplanetary space, and the others eventually fell back to Bennu's surface.

These findings suggest that all carbonaceous asteroids may be active. Future research can look for more eruptions from Bennu, Connolly said. Scientists can also search the asteroids for craters that might have originated as sites of either eruptions or impacts of erupted material, he added.

Above: The explosions may be caused by temperature changes on the asteroid



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NASA spots crash site and debris of India's lost lander

Words by Meghan Bartels

Scientists and amateurs alike have spent months combing through images from NASA's Lunar Reconnaissance Orbiter looking for the remains of India's moon lander - and that search has paid off.

On 2 December, the team that runs the Lunar Reconnaissance Orbiter Camera (LROC) instrument released images taken on 11 November that show how the spacecraft has changed the surface of the moon. Imaging experts have spotted extensive evidence of the crash, including both debris from the craft and places where the collision seems to have stirred up the Moon's regolith.

According to a NASA statement, the largest pieces of debris are each about 1.5 metres (4.5 metres) across. The Vikram lander measured 2.5 metres (8.3 feet) in its longest dimension, according to materials released by India's space agency before the landing attempt.

Left: The crash site of the Vikram lander, part of the Chandrayaan-2 mission, has been identified by the Lunar Reconaissance Orbiter

Right: The original CIMON was roughly spherical and had a cartoonish face

ISS to host new AI robot

Words by Mike Wall

The astronaut assistant known as CIMON 2 just launched for the orbiting lab aboard SpaceX's Dragon cargo capsule, which lifted off 5 December from Cape Canaveral in Florida.

CIMON 2 is following in the footsteps of the original CIMON (Crew Interactive Mobile Companion), which reached the ISS in 2018.

CIMON 2 features some significant upgrades over its predecessor, which was a technology demonstration designed to show how humans and robots can collaborate in the space environment. For example, the newer robot has been updated with the 'Watson Tone Analyzer' from the IBM Cloud, giving CIMON 2 the ability to assess and react to astronauts' emotions.

"With this update, CIMON has transformed from a scientific assistant to an empathetic conversational partner," IBM representatives wrote in a statement. "Specifically, CIMON 2 has more sensitive microphones and an advanced sense of orientation. These AI capabilities and the stability of the complex software applications have also been significantly improved in the new CIMON 2."

CIMON 2 could help lay the foundations for a powerful partnership between humanity and machine in the final frontier.

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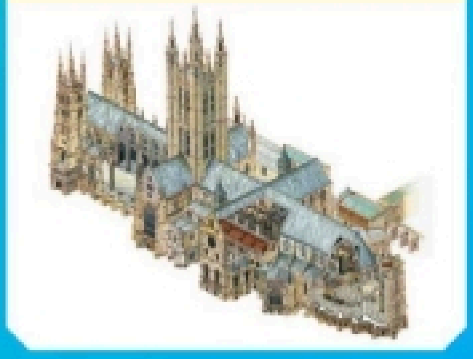

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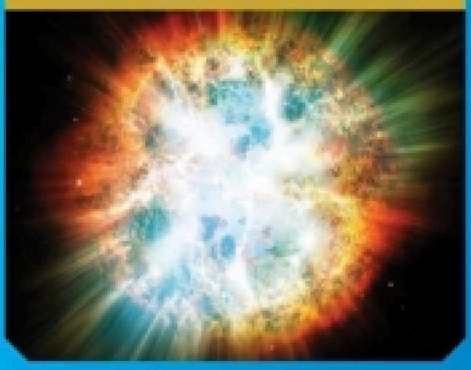

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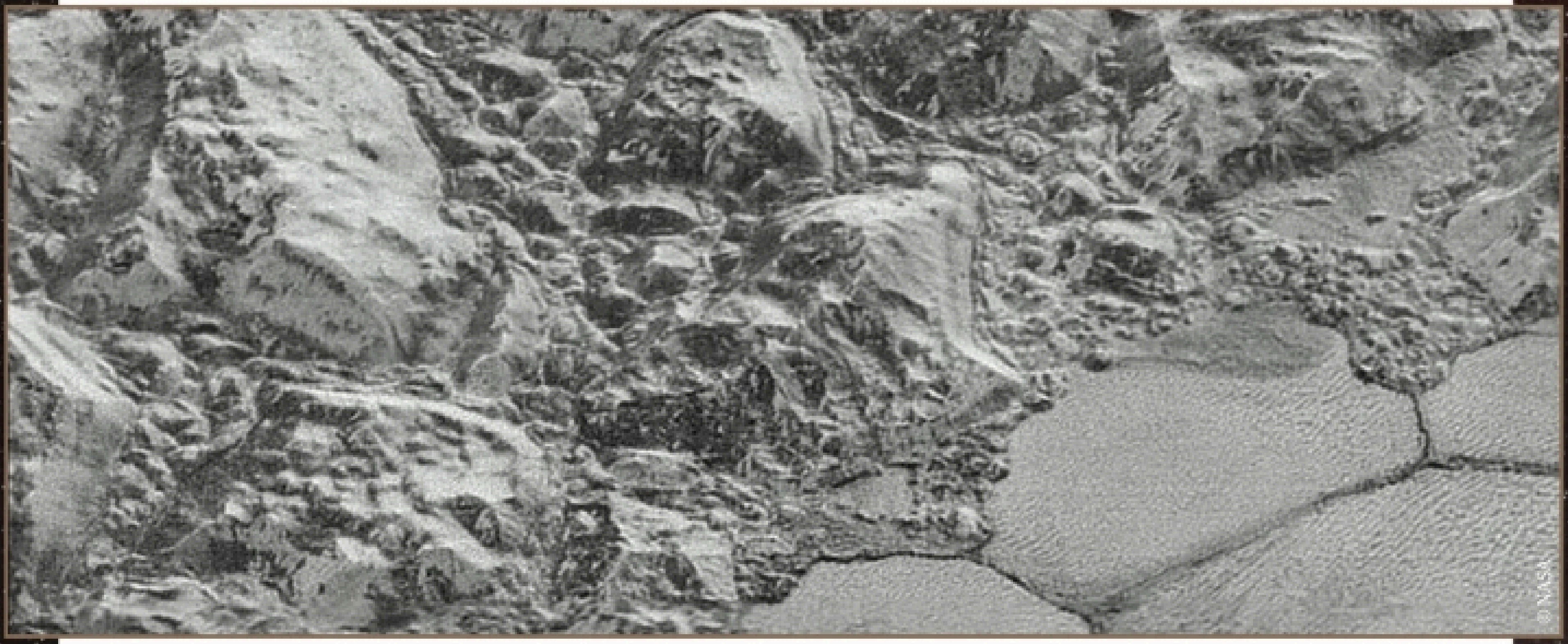
RETURN TO PLUTO

The brains behind the successful New Horizons flyby to the far-flung dwarf planet are now planning for a closer look



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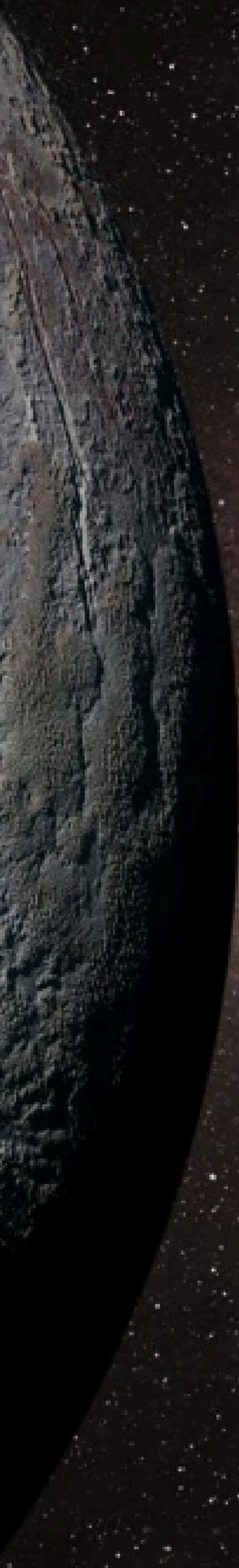


If you had dedicated 26 years of your life to sending the first-ever spacecraft to Pluto, and if you had seen that mission succeed in shedding new scientific light on this far-flung planetary system, what would you do next?

Bask in the glory or make plans to go back? For Alan Stern, the principal investigator of the New Horizons mission, it was a no-brainer. "We rewrote the textbooks in the case of Pluto. In fact, I think we wrote the textbooks from scratch," he tells **All About Space**. And there is no doubt in his mind that planetary science needs to return.

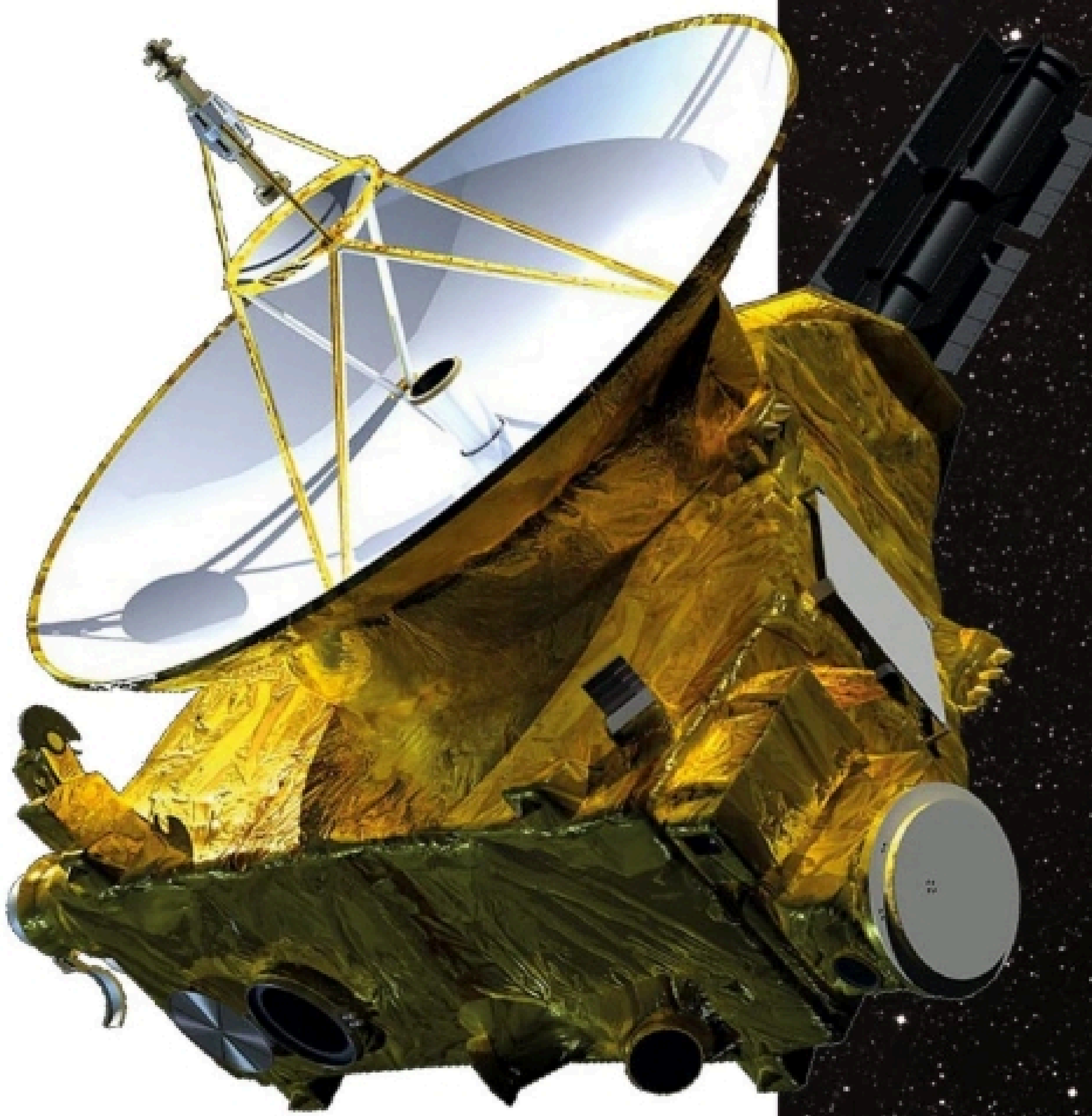
At the end of October 2019, it was revealed that such a plan is being formulated. NASA is funding a study by the Southwest Research Institute into the feasibility, attributes and cost of sending an orbiter to Pluto and its system of moons, with Dr Carly Howett, assistant director in the department of space studies at the Southwest Research Institute in Boulder, Colorado, heading a team that is looking into the development and design of the spacecraft and its payload.

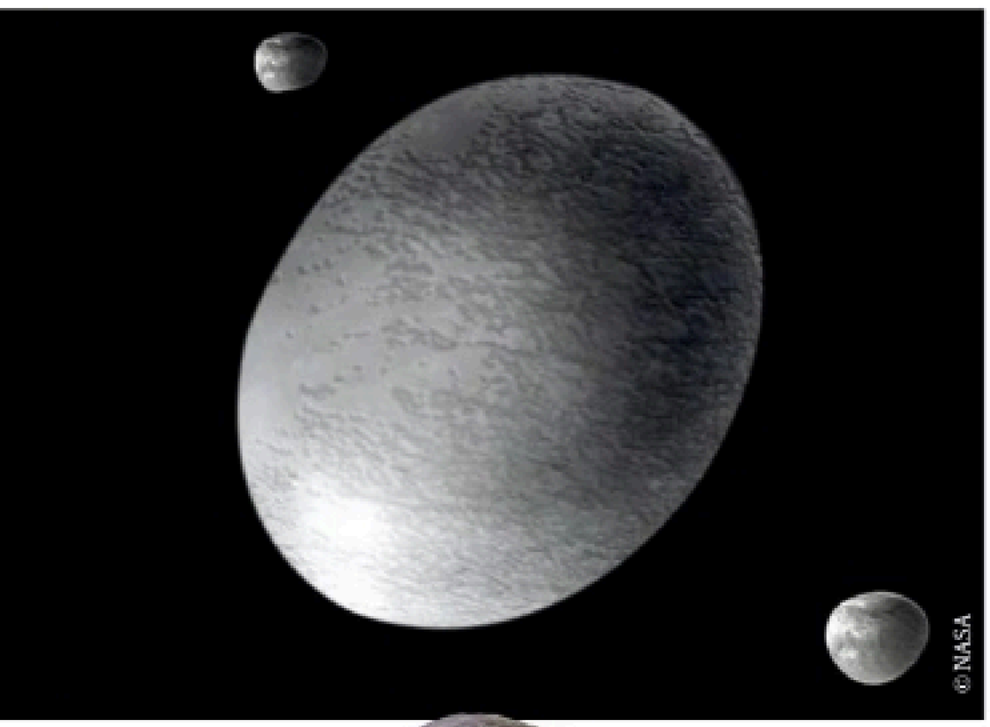
The idea is that the orbiter will analyse Pluto's system in far greater depth. "We're looking to bring back the same type of instrumentation that New Horizons had, but to do a more thorough job," Stern explains. "A first flyby was the appropriate thing to do with Pluto, but we have many questions about its geological activity and the ways in which the planet has evolved over time. There's a very wide range of scientific topics, and that will make a second mission so strong."

In order to even get off the ground, the Southwest Research Institute will need to be persuasive. The scientists need to make it into the next Planetary Science Decadal Survey, which is being prepared later this year. This publication reflects the wishes of the scientific community, and it's an important step in getting the nod – and a budget – for the mission itself. "It's just a question of whether this is the right mission to get to the top of that survey," Stern says.

If it does gain approval, it would continue Stern's career-long obsession with Pluto. In 1989, the same year he received his doctorate, he helped to set up a group called Pluto Underground with the aim of discovering more about the Solar System's farthest known planet. Frustrated that NASA's Voyager mission launched in 1977 had intended to visit Pluto but ended up leaving it unexplored, he dearly hoped to be able to one day shed light on the planet discovered in 1930 by Clyde Tombaugh.

There were certainly no plans to send a spacecraft to Pluto at that time. But the Plutophiles – as Stern has called them – were a determined bunch. A number of them met in an Italian restaurant in Baltimore to discuss a potential plan,





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and within a year a proposal called Pluto 350 emerged that was deemed light in terms of both weight and the potential money needed.

One thing's for sure, it wasn't an easy path to success. The following year, as Pluto 350 began to feel sidelined, a plan to use the Mariner Mark II concept of one spacecraft to fit multiple missions was explored and abandoned. A subsequent idea to send a lightweight spacecraft carrying just two scientific instruments was also considered, but this scheme - called the Pluto Fast Flyby that then morphed into the Pluto Express - only proved to be steps to what became New Horizons.

Throughout that time, the Plutophiles had sought support for a mission. They had recommended supporters to sit on advisory committees that would advise NASA about planetary mission priorities, written many letters to colleagues and published papers that promoted the scientific benefit of going to Pluto. But budgets, differing priorities and even White House involvement proved as tricky to navigate as space itself. Indeed, when New Horizons was officially selected for funding in November 2001, the new NASA administrator Sean O'Keefe didn't go on to include it in the budget for 2003. Thankfully it appeared in the Planetary Science Decadal Survey, and funding was finally given.

That allowed the New Horizons team just four years to design, build and test the spacecraft that would end up being launched in 2006. It was vital that the mission was ready at that point because the window would allow Jupiter to be used for a gravity assist, and Stern's team was relieved that it got off the ground in time.

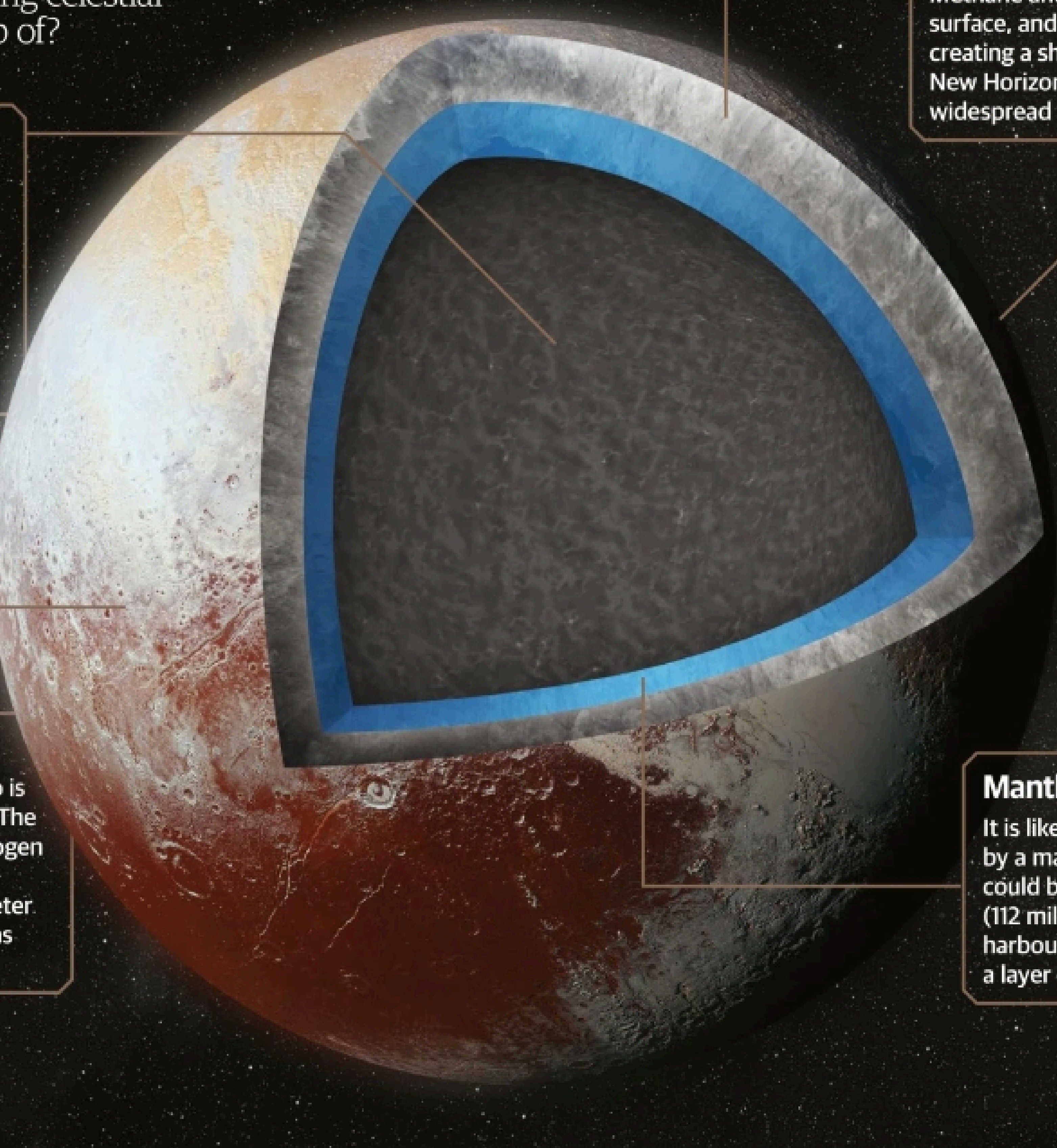
Even then, it wasn't entirely smooth. Hearts were in mouths when on 4 July 2015, contact was lost with the New Horizons spacecraft when it was just ten days away from Pluto. Although it did finally reconnect, all of the computer files needed to be re-uploaded in rapid time - something that would normally take weeks. But then, on 14 July, New Horizons performed the first-ever flyby of Pluto, getting within 12,500 kilometres (7,770 miles) of the surface and giving the world its first close-up look.

The discoveries were spectacular, revealing a variety of terrain and surface ages as well as

> "Pluto is so compelling that we should go back with an orbiter like we did with Cassini for Saturn" **Alan Stern**

Inside Pluto

Just what is this far-flung celestial body actually made up of?



Rocky core

At Pluto's heart is a dense, rocky core that is said to be 1,700 kilometres (1,056 miles) in diameter. That makes up some 70 per cent of the dwarf planet's overall diameter of 2,370 kilometres (1,473 miles).

On the surface

With minimal air pressure Pluto is certainly no place for humans. The surface has valleys, frozen nitrogen gas plains, craters up to 260 kilometres (160 miles) in diameter and mountains that are as tall as three kilometres (1.9 miles).

A covering shell

Methane and nitrogen frost coat Pluto's surface, and there is a possibility that it is creating a shell across the dwarf planet. New Horizons showed that water ice was widespread across the surface.

What an atmosphere!

As ice thaws, it evaporates into the thin atmosphere as molecular nitrogen with a hint of methane and carbon monoxide. The atmosphere can freeze and fall as snow as it moves away from the Sun.

Mantle of ice

It is likely that the core is surrounded by a mantle of water ice, which could be as thick as 180 kilometres (112 miles). In fact, Pluto could be harbouring a liquid ocean insulated by a layer of gas from an ice covering.

suspected ice volcanoes, vast nitrogen glaciers, evidence of a possible liquid water ocean inside and data that pointed to higher surface pressures in the past. Organic compounds were also evident, and there were startling finds regarding Pluto's moons, including the reflective surface of the largest, Charon.

But as more and more discoveries continued to be made, they raised ever more questions, prompting a push to return for a more in-depth study. "One of the philosophies since the exploration by New Horizons is that Pluto is so compelling that we should go back with an orbiter like we did with Cassini for Saturn or Galileo for Jupiter," says Stern. "That's a vertical, very deep approach, and it has been a conversation that we've been having for four years."

There is a general consensus among scientists that revisiting that part of the outer Solar System would be desirable, yet there is a debate over whether the focus should be entirely on Pluto. California Institute of Technology astronomer Mike Brown says further studies should be widespread. "Pluto is a fascinating place, and there are many things we would still like to know about it," he tells **All About Space**. "But to me, what is interesting about the outer Solar System and the Kuiper belt is the diversity of bodies out there beyond Neptune."

Brown is well known. He calls himself the 'Pluto Killer' since he was instrumental in the International Astronomical Union's decision to demote the celestial body from planet to dwarf planet status in 2006. It's interesting to note that current NASA administrator Jim Bridenstine has repeatedly affirmed in recent months that Pluto is a planet, effectively siding with Stern in the ongoing sideline debate. In Brown's eyes, however, it shouldn't get special attention.

"There is Haumea, which is an oval-shaped rocky body covered in a thin layer of ice spinning every four hours with two moons and a ring," he says. "There is Makemake, covered in what looks like slabs of methane ice so thick you could ice skate on them, and there is Quaoar, which looks to be a weird transition-type object a little like Pluto and a little like Charon. The list goes on.

"I understand the feeling of wanting to go back somewhere where there were so many interesting things, but rather than filling in the details on Pluto it makes much more sense to continue the basic exploration of the entire region."

As things stand, Stern is entirely on board with such concerns. "There is an opposing philosophy that we should sample the diversity of objects in the Kuiper belt, big and small, rather than return to Pluto," he says. "But we have made a breakthrough in this regard. My institution spent close to $500,000 on funding a major study into the development of a Pluto orbiter, and we found that it is actually possible to orbit the planet, use gravity assists from its largest satellite Charon, skate the system and then go back to the Kuiper belt.

"It means the proposed mission is removing any debate over whether we go broad or go deep. We can do both with a single launch of a single spacecraft mission and cover both Pluto and other Kuiper belt objects. It is something we are calling the Gold Standard, and it's really exciting because we don't have these two warring factions. We do it all and at a much lower cost than carrying out both missions individually."

Stern says the combined mission would merely mean a longer operation phase, since the same launch vehicle and flight to Pluto would be involved. It also adds just 20 per cent to the cost of a follow-up solitary Pluto mission. "Imagine those two-for-one deals," Stern says. "This is two

Top left: The planned orbiter would explore both Pluto and other dwarf planets, including Haumea

Left: Alan Stern is the principal investigator of New Horizons and is also heavily involved in a successor orbiter mission

Below: The Southwest Research Institute has funded a feasibility study into a Pluto orbiter

Below left: New Horizons rewrote the textbooks, says Stern, and the proposed orbiter should add some more chapters

Temperature of Pluto

Earth's hottest recorded air temperature:
56.7°C (134.1°F) at Furnace Creek, California, 1913
Human body (average):
37°C (98.6°F)
Snow and ice:
0°C (32°F)
Ideal freezer temperature:
-18°C (-0.4°F)
Earth's lowest recorded ground-level temperature:
-89.2°C (-128.6°F) at the Soviet Vostok Station, Antarctica, 1983
Moon temperature range:
-248 to 123°C (-414 to 253°F)
Liquid nitrogen freezes:
-210°C (-346°F)
Surface of Pluto:
-226 to -240°C (-375 to -400°F)
Liquid hydrogen boils:
-252.87°C (-423.17°F)
Absolute zero:
-273.15°C (-459.67°F)

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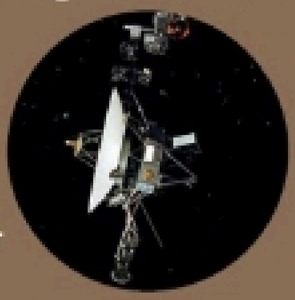
How we got to Pluto

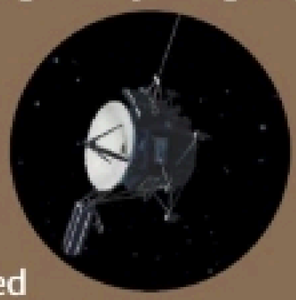
New Horizons was the first spacecraft to visit Pluto, but there were plenty of proposals for a mission before it

Voyager 1 – 1977



After Voyager 1 launched, there were plans to fly to Pluto in March 1986. They were dropped in favour of Saturn's moon Titan. Voyager 2 also skipped past since Pluto's alignment made an encounter impossible.

Pluto 350 – 1990



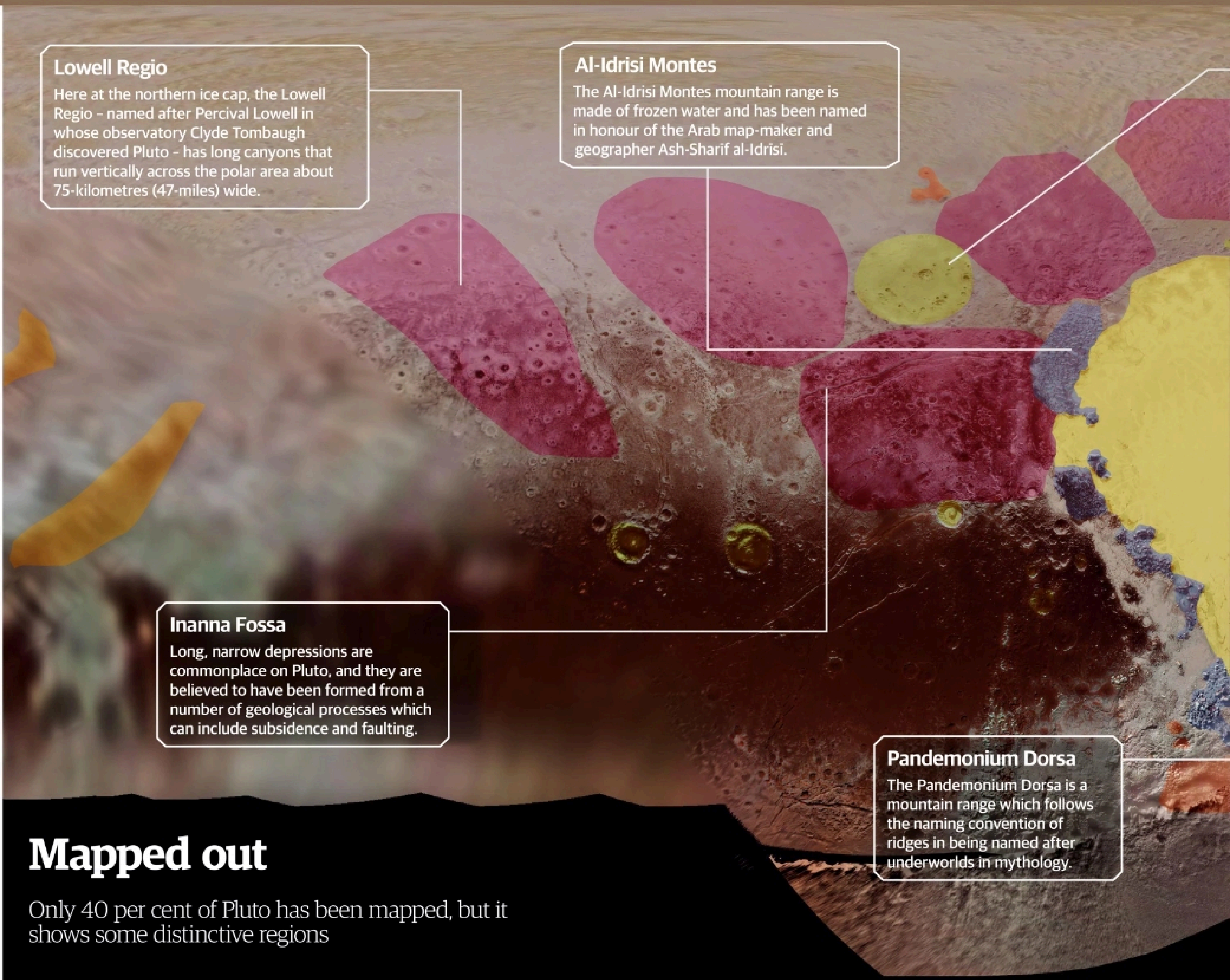
When Voyager 1 completed its flyby of Triton, Robert Farquhar of the Goddard Space Flight Center looked into a mission to Pluto, called Pluto 350. The spacecraft was to weigh just 350 kilograms, travel fast and be cost-effective.

Mariner Mark II – 1991

A project that aimed to create a series of spacecraft for the exploration of the outer Solar System. After planned missions to Saturn and Titan, attention was paid to Pluto, but Mariner Mark II was deemed too expensive.

Mapped out

Only 40 per cent of Pluto has been mapped, but it shows some distinctive regions



Lowell Regio
Here at the northern ice cap, the Lowell Regio – named after Percival Lowell in whose observatory Clyde Tombaugh discovered Pluto – has long canyons that run vertically across the polar area about 75-kilometres (47-miles) wide.

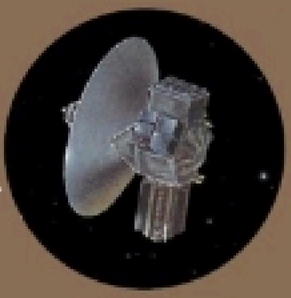
Al-Idrisi Montes
The Al-Idrisi Montes mountain range is made of frozen water and has been named in honour of the Arab map-maker and geographer Ash-Sharif al-Idrisi.

Inanna Fossa
Long, narrow depressions are commonplace on Pluto, and they are believed to have been formed from a number of geological processes which can include subsidence and faulting.

Pandemonium Dorsa
The Pandemonium Dorsa is a mountain range which follows the naming convention of ridges in being named after underworlds in mythology.

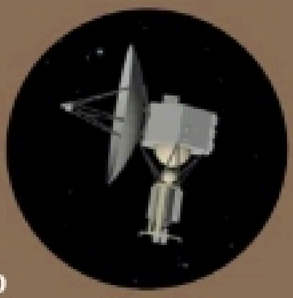
> "It is actually possible to orbit the planet, use gravity assists from its largest satellite Charon, skate the system and then go back to the Kuiper belt" **Alan Stern**

Pluto Fast Flyby – 1992



NASA's JPL devised the Pluto Fast Flyby mission concept as a cheaper alternative to both the Mariner Mark II and Pluto 350 proposals. Weighing no more than 50 kilograms, it was to fly two spacecraft to Pluto.

Pluto Express – 1995



The Pluto Fast Flyby advanced over a number of years, and it became known as Pluto Express in 1995. But it was still considered too expensive even when the concept was subsequently scaled back to a single spacecraft.

New Horizons – 2006

17 years after a dozen planetary scientists got together, called themselves Pluto Underground and sought ways of getting to the then-planet, New Horizons launched. It made its closest approach to Pluto on 14 July 2015.

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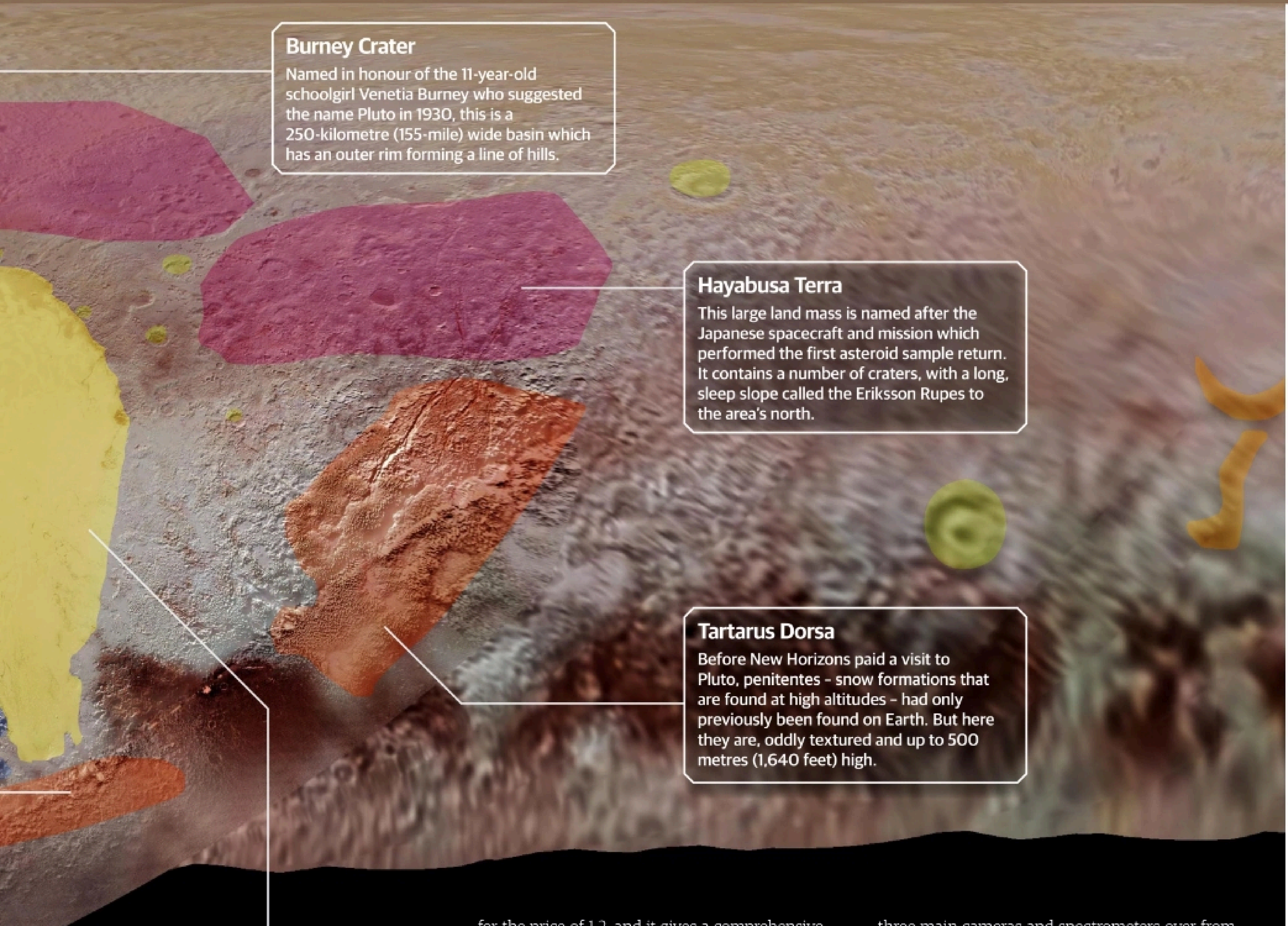


Burney Crater

Named in honour of the 11-year-old schoolgirl Venetia Burney who suggested the name Pluto in 1930, this is a 250-kilometre (155-mile) wide basin which has an outer rim forming a line of hills.

Hayabusa Terra

This large land mass is named after the Japanese spacecraft and mission which performed the first asteroid sample return. It contains a number of craters, with a long, sleep slope called the Eriksson Rupes to the area's north.

Tartarus Dorsa

Before New Horizons paid a visit to Pluto, penitentes – snow formations that are found at high altitudes – had only previously been found on Earth. But here they are, oddly textured and up to 500 metres (1,640 feet) high.

Tombaugh Regio

Nicknamed 'the heart' because of its distinctive shape, the Tombaugh Regio – so-called after the discoverer of Pluto, Clyde Tombaugh – contains Sputnik Planitia, a vast ice field on the western lobe that is 1,000-kilometres (620-miles) wide.

© NASA

for the price of 1.2, and it gives a comprehensive study of Pluto, the Kuiper belt and additional dwarf planets."

This makes the proposals doubly exciting, though, since the new mission would bridge many knowledge gaps. New Horizons was only able to get good resolution shots of 40 per cent of Pluto's geology and surface composition since it was flying by at speed. "Less than half of Charon was mapped and we barely touched the small satellites," Stern says. "The same goes for surface composition and atmospheric studies, so what we will do is bring the three main cameras and spectrometers over from New Horizons to do a more through job of mapping every object and watching for variability. We know Pluto's atmosphere is changing, and we'll be able to gather accurate data."

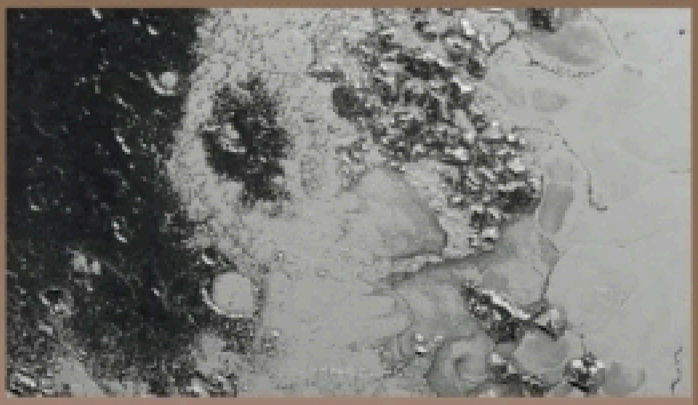
He also says New Horizons discovered that Sputnik Planitia, a high-albedo ice-covered basin on Pluto, is convecting, and that there are avalanches and cryo volcanoes. "We want to add new types of instrumentation including ice-penetrating radar called lidar to measure the depth of glaciers and other ice deposits," he continues.

Breakthrough discoveries

What has New Horizons already told scientists about Pluto and the Kuiper belt?

A complex world

With mountains, faults, polar caps, ice volcanoes, ground fogs and more, Pluto took even the New Horizons team by surprise. Meanwhile, large chasms and a north pole covered with material that had escaped from Pluto's atmosphere were seen on the moon Charon.



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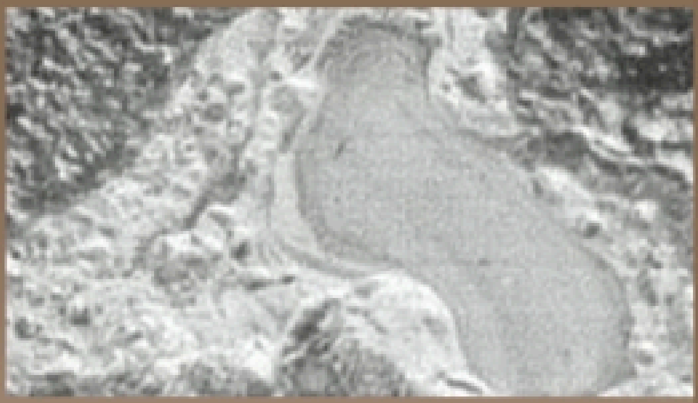
Ocean of liquid water

New Horizons showed that the giant glacier Sputnik Planitia – a vast, deep layer of nitrogen ice – is aligned with Pluto's tidal axis, with Charon overhead exerting a gravitational pull. To have moved there via tidal forces, a liquid-water ocean layer would need to be under the crust.



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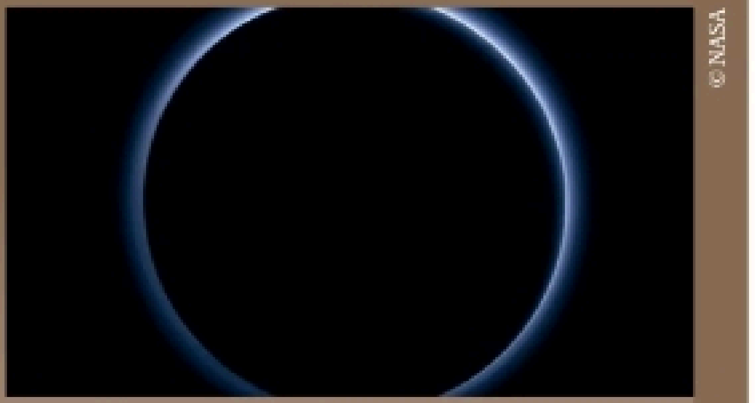
Loss of nitrogen is slow

The gravity on Pluto is 0.066 that of Earth's, and because it is so low, with a low escape velocity, scientists did think that methane and nitrogen would be escaping very quickly. But it's not – it is 10,000-times slower. The atmosphere is nitrogen rich and methane poor.



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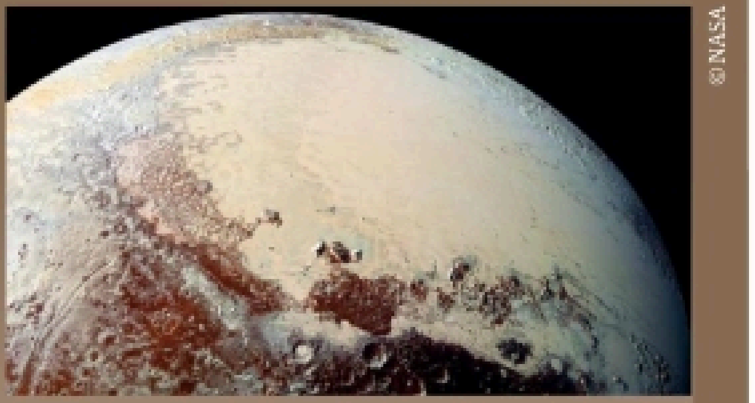
Pluto is geologically active

Pluto was expected to be a relatively dead world, but it was shown to have been active throughout its history. A heart-shaped feature suggests processes are smoothing the craters seen elsewhere, with evidence of tectonic features and bulk flow similar to terrestrial glaciers.



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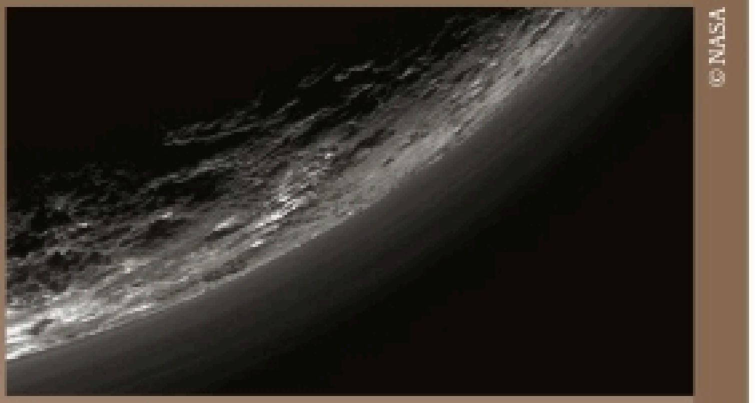
An extensive haze

The atmosphere is a haze made up of some 20 layers. It covers the entire dwarf planet, hanging in the cold nitrogen air at an altitude of more than 200 kilometres (124 miles). Created from complex chemistry in the atmosphere, it's said to keep Pluto cooler than expected.



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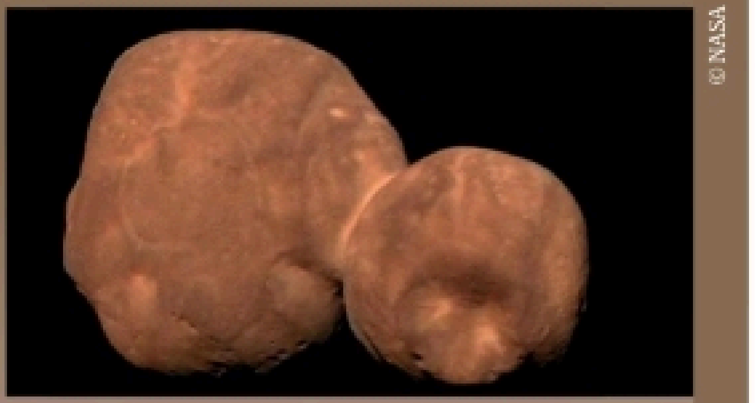
Imaging of a faraway object

On 1 January 2019, New Horizons visited the most distant object ever explored – the snowman-like asteroid 2014 MU69. Located in the Kuiper belt, It was recently renamed Arrokoth, and it showed a prominent crater on the smaller of its two lobes as well as troughs and hills.



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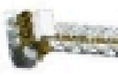
Above: NASA administrator Jim Bridenstine told the International Astronautical Congress in November 2019: "I believe Pluto should be a planet"

Right: The proposed orbiter will be able to get a proper look at the dark side of Pluto



"These laser ranging-altitude detectors can map the surface at very high accuracy to gather geological topography data. Thermal mappers can also look for hotspots in the glaciers and in the volcanoes in other regions. Mass spectrometers will sample the composition of the atmosphere and a magnetometer can let us know if the planet's core is alive and churning or dead and frozen solid."

It'll be possible to determine how the temperature changes when the Sun goes down on the night sides of Pluto and its moons and, because the orbiter will be sticking around for a while, seasonal changes can be monitored too. "New Horizons gave us information on a particular day, but an orbiter that stays for years will be able to study atmosphere and geological changes over a long period of time. We'll be able to compare the geology and the atmosphere in the year 2015 to the data when the orbiter arrives in the 2030s, 2040s or whenever."

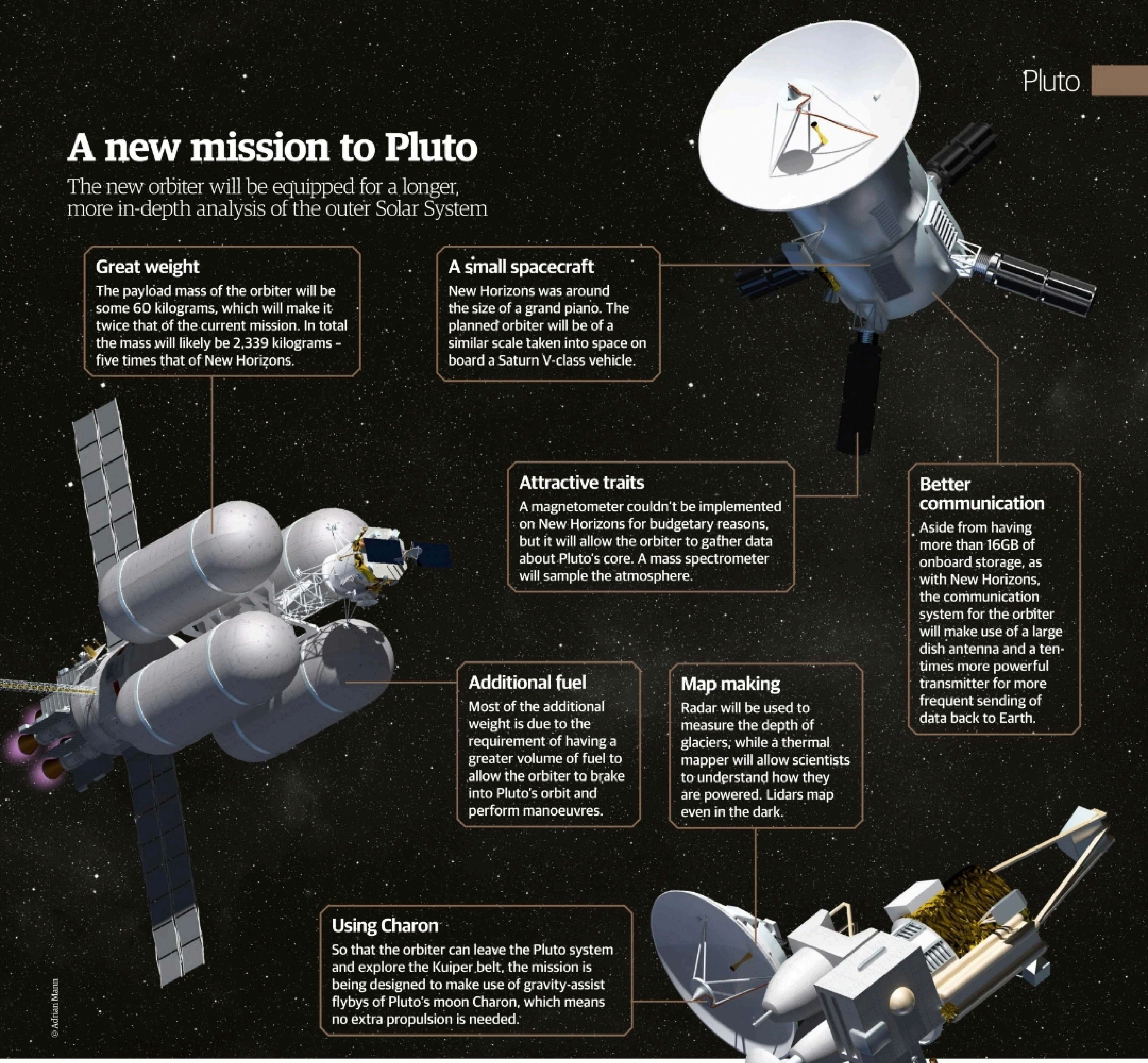
Certainly, the mission is not about to be sending information back imminently. The findings of the Planetary Science Decadal Survey are expected in 2022, which would allow for a launch no sooner than December 2028. On that timescale there would be a gravity-assist flyby of Jupiter in October 2030 and a braking into Pluto's orbit in 2046 – a process that will take 13 years.

Stern says it could be sped up if nuclear systems can be used to increase the braking thrust so that it slows faster. "The orbiter has to stop and not just fly by, so it will carry a lot more fuel and a different type of propellant that is much more efficient," he continues. "It would use a Saturn V-class launch vehicle and a nuclear electric stage augmented by a chemical propulsion braking system."

As well as more instrumentation, higher communication rates are needed too. "With New Horizons we intentionally sacrificed communications bitrates to save money, and it allowed it to be affordable. But even in the 1970s-era Voyager missions there were ten-times higher data rates at the same distance, and today

A new mission to Pluto

The new orbiter will be equipped for a longer, more in-depth analysis of the outer Solar System



Great weight

The payload mass of the orbiter will be some 60 kilograms, which will make it twice that of the current mission. In total the mass will likely be 2,339 kilograms – five times that of New Horizons.

A small spacecraft

New Horizons was around the size of a grand piano. The planned orbiter will be of a similar scale taken into space on board a Saturn V-class vehicle.

Attractive traits

A magnetometer couldn't be implemented on New Horizons for budgetary reasons, but it will allow the orbiter to gather data about Pluto's core. A mass spectrometer will sample the atmosphere.

Better communication

Aside from having more than 16GB of onboard storage, as with New Horizons, the communication system for the orbiter will make use of a large dish antenna and a ten-times more powerful transmitter for more frequent sending of data back to Earth.

Additional fuel

Most of the additional weight is due to the requirement of having a greater volume of fuel to allow the orbiter to brake into Pluto's orbit and perform manoeuvres.

Map making

Radar will be used to measure the depth of glaciers, while a thermal mapper will allow scientists to understand how they are powered. Lidars map even in the dark.

Using Charon

So that the orbiter can leave the Pluto system and explore the Kuiper belt, the mission is being designed to make use of gravity-assist flybys of Pluto's moon Charon, which means no extra propulsion is needed.

© Adrian Mann

we could do faster still – maybe 50 or 100-times as fast as New Horizons.

"When New Horizons swept by Pluto, it took 16 months to get all the data back. But with 50 or 100 times the transmission power, we will be able to empty the data recorders every week and do so again and again over many years. This won't require a technological breakthrough because it was done in those Stone Age 1970s."

Even so, what is perhaps most daunting is that to get the mission off the ground, the team will still have to do some persuading and keep within budget. "But that's just the way life works," Stern reflects. "I'd like to have breakfast in bed every morning but I'm not going to get it, just as we won't get everything we want in every mission. We do have many ideas, and there are more than I'm sure there is room for on the next spacecraft, but there's only a certain amount of money."

He is definitely convinced of the merit of a second stab at covering that particular area of the universe, though. "Pluto and the Kuiper belt can stand on their own two feet, and they are enormously scientifically attractive, rivalling many other kinds of enterprises in planetary exploration," he says.

"I'm ready to help make that next stage happen and use the mission to discover what's on the other side of Pluto, find out more about the small satellites on the other side of Charon and answer questions about geologic activity and the way Pluto has evolved over time. Yet I can't predict discoveries. Only the universe will tell us what is out there."

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Right: An artist's impression of a young, chaotic planetary system

ICE FOSSILS REVEAL CLUES TO OUR PAST

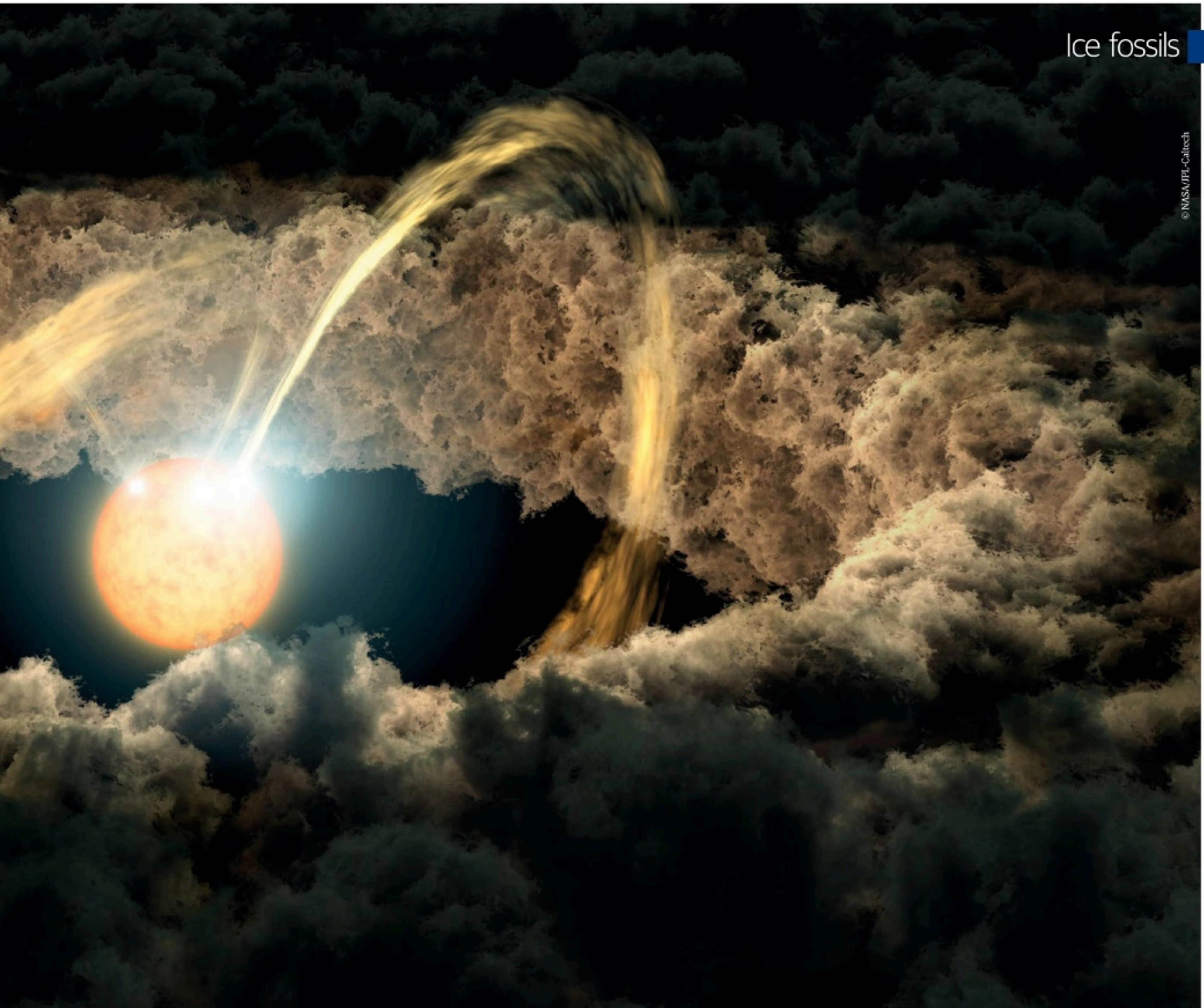
An ancient space rock's artefacts have revealed tantalising insight into the conditions of our early Solar System

Reported by Chelsea Gohd

Scientists have discovered ancient asteroid ice fossils that could reveal what our Solar System was like billions of years ago.

In a new study, scientists analysed a 4.6-billion-year-old primitive meteorite, called Acfer 094, that crash-landed in the Sahara Desert in Algeria in 1990. A primitive meteorite is a rocky remnant of the solar nebula, or the gaseous cloud that some say condensed into the objects in the Solar System, that has fallen to Earth. Within the meteorite scientists found what seem to be ice fossils, and the discovery is helping to illuminate how asteroids formed in the early Solar System and what the materials that eventually formed our neighbouring planets may have looked like billions of years ago.

The researchers discovered what they think are the remnants of fluffy ice dust, or porous silicate, sulphide and organic material that make up "one of the building blocks of planets in the Solar System formation model," Megumi Matsumoto, lead author of the study, revealed. These fluffy ice-dust remnants, also known as ultra-porous lithology, look



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like tiny "fluffy aggregates of silicate grains covered with an H_2O icy mantle," said Matsumoto.

The pores in this material were likely created when ice that previously filled the space disappeared, the team found. By finding the pores, they discovered evidence of this ancient ice.

In the early Solar System, swirling dust, gas and sometimes ice compacted and formed objects like rocky asteroids or even larger protoplanets – astronomical objects about the same size of the Moon that are formed when planetesimals, or small solid astronomical objects, combine. And some of these small, newly formed protoplanets contained ice. As they grew they heated up, and that early Solar System material they started with started to melt and recrystallise.

These findings allow researchers to look back in time at the material that eventually formed objects like asteroids and the planets in our Solar System. The study vastly improves scientists' understanding of how those materials came to form those objects.

Researchers have previously identified interactions between water and rocks that happened when ice melted in the larger objects that broke off into objects like Acfer 094. However, until now it has remained a mystery how this ice got there, Matsumoto said.

> "In the early Solar System, swirling dust, gas and sometimes ice compacted and formed objects"

The discovery of the asteroid ice fossils reveals how primordial ice was "brought into and distributed to the meteorite parent body," Matsumoto said. Using a model that simulated how Acfer 094 grew and how the planets in the Solar System formed, the researchers determined that fluffy ice and dust particles came together in bigger bodies beyond the snow line – the distance from the Sun where it's cold enough for solid ice grains to form – and then migrated towards the Sun, Epifanio Vaccaro, curator of petrology at the Natural History Museum in London, said in a statement. As these bodies moved inward towards the Sun, this ice started to melt, leaving the ice fossils in its place, he said.

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INTERVIEW BIO

Professor Chris Lintott

Chris Lintott is a professor of astrophysics at the University of Oxford, UK, and also the principal investigator of the Zooniverse. This is the world's most successful citizen science project, with over a million people worldwide contributing to a variety of science and history projects.

He has also co-presented the BBC's *Sky at Night* programme, as well as contributing to another BBC astronomy programme *Stargazing Live*. His latest book *The Crowd and the Cosmos: Adventures in the Zooniverse*, explores the world of citizen science and what it has to offer to enthusiastic volunteers.

"I'M THE WORLD'S MOST DISTRACTED ASTRONOMER"

Citizen science is the backbone of astronomical discoveries. Professor Chris Lintott speaks to **All About Space** about his popular project, the Zooniverse, and how it's continuing the tradition with great success

Interviewed by Lee Cavendish

How would you explain 'citizen science' to someone that isn't aware of it?
I think to astronomers in some sense it's old news, because astronomers - of all stripes - have been contributing to science for centuries. You can go right the way back to the first studies of variable stars, or the people who kept an eye on storms on Jupiter in the 19th century, and you discover that there were plenty of people who were well resourced and had telescopes in their backyard.

I remember growing up, realising that I was sort of getting interested in astronomy at the time and that amateur [astronomers] were getting serious about supernova hunting. People like Tom Boles and Mark Armstrong were discovering the first British supernovae. Citizen science is as simple as the idea that anyone can do science, whereas what has happened now is that we all have access to large data sets produced by professional astronomers and professionalised observatories. We need help sorting through the data, and that's really the new thing that's happened in the last few years. We've got professionals who have got so good at collecting data that they are overwhelmed - that's where we need help.

A chapter in your book talks about the history of crowdsourcing. Do you think it's evolved since the days of Edmond Halley crowdsourcing observation of a solar eclipse in 1715, or do you think it's been as strong as it ever was?
There's some evidence in the 20th century where science becomes professionalised. Towards the end of the 19th century, people started getting paid to be astronomers for the first time. I think in the 20th century, cutting-edge science was a bit more - not entirely, of course - but was a bit more centralised towards professionals. In the 21st century, because we built these communication and digital technologies, we're back to the point where everyone could communicate. I think it's an old idea, but with a very 21st-century spin on it.

A term you use a lot in the book is 'proper science'. How would you define proper science?
What I'm trying to say is that anything that contributes is proper science. I think we're very bad at teaching what science is actually like. I think people have this idea of proper science which probably involves somebody in a lab coat, probably with some purple, bubbling liquid. Or maybe it's a professor in front of a blackboard with some chalk and the word 'eureka'. But the people who build cameras for observatories are doing science. The people who literally grease the wheels of the telescopes are doing science. The people who are online in the Zooniverse projects and looking at the data for the first time are doing science.

Part of it is that science is this great collective effort, and a lot of us can play a part in it. We don't have to be the person with the bubbling liquid or the person solving the equations to be a scientist. I also think there's a promise in that when we ask people to look at galaxies on Galaxy Zoo or to look for planets on Planet Hunters, or whatever it is, I think there's a guarantee that from us, we're going to use those results.

Could you tell us a bit about the variety of the projects that are on the Zooniverse website?
I usually describe myself as the world's most distracted astronomer. We didn't set out to do this deliberately. We were just trying to solve an astronomy problem. But it turns out that we're not the only ones who have had this problem of creating too much data. Pretty much as soon as we launched the project, we started to get other people approaching us. Now we've done all sorts of things, from working with amazing microscopes to historical texts and other things.

I think my favourites, or at least the area that is instinctively interesting, are the ecology projects. Ecology is fascinating, partly because the science is interesting, but I hadn't really realised it's a bit like astronomy in that it's a science where it's hard to do experiments. If I want to understand how galaxies merge, I can simulate them on a computer, but I can't really crash Andromeda and Triangulum together tomorrow and see what happens - probably just as well. If I want to understand cheetah's behaviour, yes, I can simulate them on a computer, but I'm not allowed to put a cheetah in a park with seven antelope and see what happens.

So you've got the same sort of problem. You've got a set of information that you've observed. There

Left: Lintott is interested in how galaxies form and evolve, and his PhD thesis surrounded the early stages of star formation

Right: Lintott believes that astronomy and ecology have similarities, using colliding galaxies as an example

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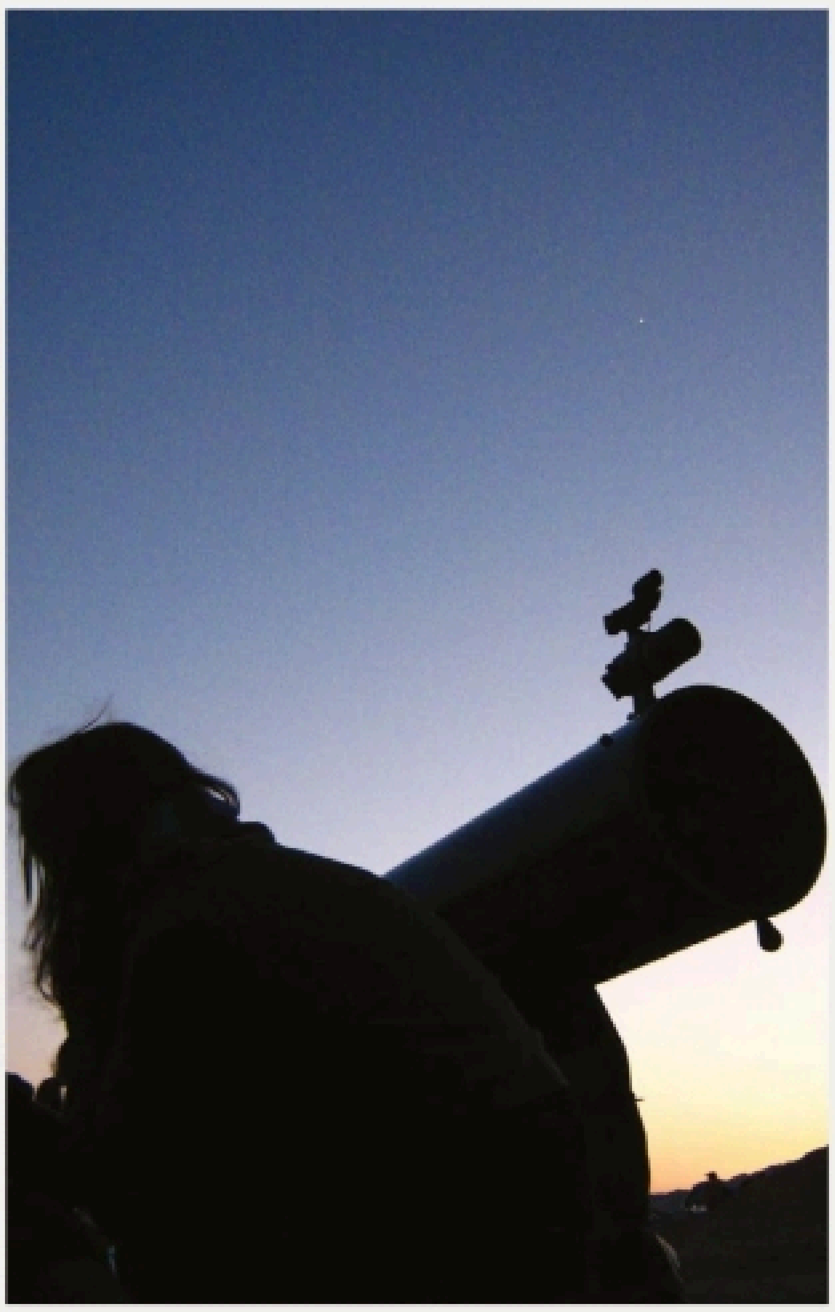
"Part of it is that science is this great collective effort, and a lot of us can play a part in it"



Source: Wikipedia Commons © Ilan Shimony

are all sorts of biases and so on, and the scientific trick is to make use of that information.

When you look back over the last decade or so since Galaxy Zoo's inception, what have been some major milestones in the project?
Day one of Galaxy Zoo was the most surprising day of my life. We thought we were launching a tiny project that a few thousand amateur astronomers might help us with. I just remember sitting looking at the email inbox and realising that in the first half an hour of a project, we had got 20,000 emails. Now, most of those emails said 'your site isn't working' because it was buckling under the pressure, so day one was very important.

Getting the first Galaxy Zoo paper accepted was a big deal, because we had this idea that this had to be real science - it had to be authentic science. I had a quarter of a million collaborators whom I promised we would make use of this data, so being able to see other astronomers take on that data and use it was good.

I think the moment I really realised that this wasn't going to be a flash in the pan was when Planet Hunters launched. I have a long track record of being wrong about many things. This was one of the things I was wrong about. I remember sending an email to the team saying that I was not sure we should be launching this project. I'm not sure that we're going to find anything. But I'd talked myself into launching it because if we fail, we'll learn something about what we can and can't do. Then pretty quickly after launch we had a couple of candidate exoplanets, and Planet Hunters is still an enormous success.

Just as a personal high point, the projects we did with *Stargazing Live*, where we set ourselves the challenge of producing results in two days. I don't know how it comes across on camera. Dara [O'Briain] and Brian [Cox] are great fun, and it has been good to do those things. But I didn't sleep for those two days.

What are the advantages of having citizen scientists over using artificial intelligence?
There are a few. One of them is that there are still many places where humans are better than computers. I just had a call with my PhD student Mike Walmsley, who's briefly in the book and who's our artificial-intelligence expert. We were arguing about why humans are better at finding bars in spiral galaxies than his machine. And one of the reasons is that our visual system is very good at taking in information on different scales at once.

Another answer is that people are distractible, which is sort of the theme of the book, I guess, that people can be distracted by the unusual and the unexpected. Lots of the great discoveries have come from when people have found things that they weren't expecting, or that we didn't ask them to look for. And that goes all the way back to Galaxy

Zoo, but it's still happening today. The ability to be doing one task, and then go "hang on. There's something weird here" is very natural and very human. It's actually something that volunteers are better at than experts. Experts have a hard-coded understanding of what they should be looking at.

Do you think artificial intelligence will ever get to a point where it is up to that standard?

I think that's an open question. My flippant answer is that I've spent ten years with machine learning people telling me that if they had an afternoon, they could solve these problems. And it always turns out they can get 80 per cent of the way there. What we're really finding though is that because the data sets keep growing, a combination of human and machine is really powerful.

For many of the problems that we're dealing with, as the data sets get larger and larger, we definitely need machine learning to do most of the work for us. There's no way we're going to cope with the information that's coming from future telescopes without machines doing the bulk of the work. But, if you take humans and put them in the loop, not only do you get a better result by combining them, your machine can also do better. My bet is that we are going to have hybrid systems.

A telescope you mention towards the end of the book is the Large Synoptic Survey Telescope (LSST), which is going to produce ridiculous amounts of data in just a single night. Do you have plans to collaborate and use this data for citizen science projects?

The LSST is an amazing project. I've been involved with it for most of the time I've been doing Zooniverse, and it's the first observatory that's planning, from the start, to have citizen science. For astronomers using LSST data it will be really simple for them to connect to Zooniverse and talk to our volunteers.

There is an army of postdocs around the world building routines for their special subject, so if you study Type II supernovae and you write good code, you will be able to get the LSST to give you more Type II supernovae than you've ever dreamed of. And that's cool. The problem is if you want to be surprised.

We have citizen science in the loop. We will take the weirdest stuff that the machine doesn't understand and we will pass those to people. There's some urgency, because one of the things that's happening in astronomy is we're realising things in the sky change faster than we expect.

I think we're ready. We've got a solution. And then I think the task will be to be as flexible as possible. I haven't, for example, tried to bet on which specific science cases will need citizen science in five years time with the LSST. I'm just pretty sure there will be some.

In the book you talk about how astute you are in assessing your contributors, and especially with the Space Warps project. How much effort goes into ensuring that valuable data is assessed correctly?

It's a big effort, actually. I don't quite like thinking about the Zooniverse like this, because it sounds a little callous, but one way of testing what we're doing with the Zooniverse is to think of it as a black box.

The Zooniverse is a black box that analyses astronomical images. And if I brought that black box and handed it to my colleagues and said "this will solve all your problems," they would spend six to nine months testing it to make sure it did what they expected and so on. We have to do the same with the Zooniverse, even though the box contains 1.6 million people. It's the same sort of tasks that we have to do when we are building a new machine learning algorithm and so on.

It's fascinating. We've looked at all sorts of things. At one point we looked at whether there was a time of day, or time of the week, that people were better at classifying. I was slightly worried that it would come out that people were great at 11pm on a Friday, after a few beers. It turned out that it was pretty flat.

The truth is that for most of our projects, most people are pretty good or become pretty good with experience. That's useful, and we test that. Partly we're doing it to make sure that we're living up to this promise that people really are making a useful contribution.

What are your thoughts on making, for example Planet Hunters, into a game interface to try and make it more interactive?

I think that it's an interesting route. There are people who've done this, but not particularly in astronomy. But my sense is partly fear. Writing a good computer game is really hard. I'd say writing a good game that also happens to find planets is really, really, really hard, so partly we've avoided it for that. Also we found that people take part in these projects because they want to help. That was the big surprise early on. When we tried this sort of thing, we found that people changed how they talked about the project. Instead, when you don't make it a game, and specifically when you don't make it a competition, people talk about the project as something joyful and inspiring. Then the moment you make it a competition, they talk about it as if it's work. It becomes stressful. "I had to log on this morning" as opposed to "I was excited to".

Games are really powerful. As a species, we like playing games and competitions. I try and keep the two a bit separate and make sure that people know that they're doing science. We're not seriously sitting in ranks all during our science work, but there is a seriousness of purpose there that I think is really, really important.

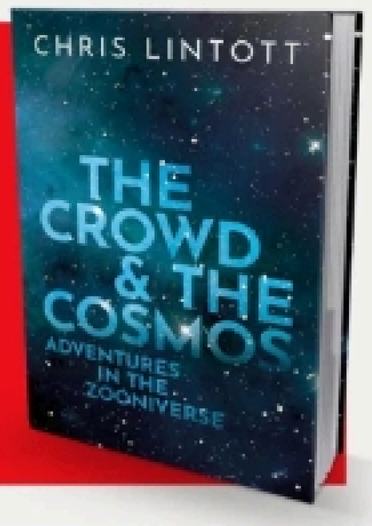
Top left: Zooniverse participants are better at identifying bars in spiral galaxies than artificial intelligence

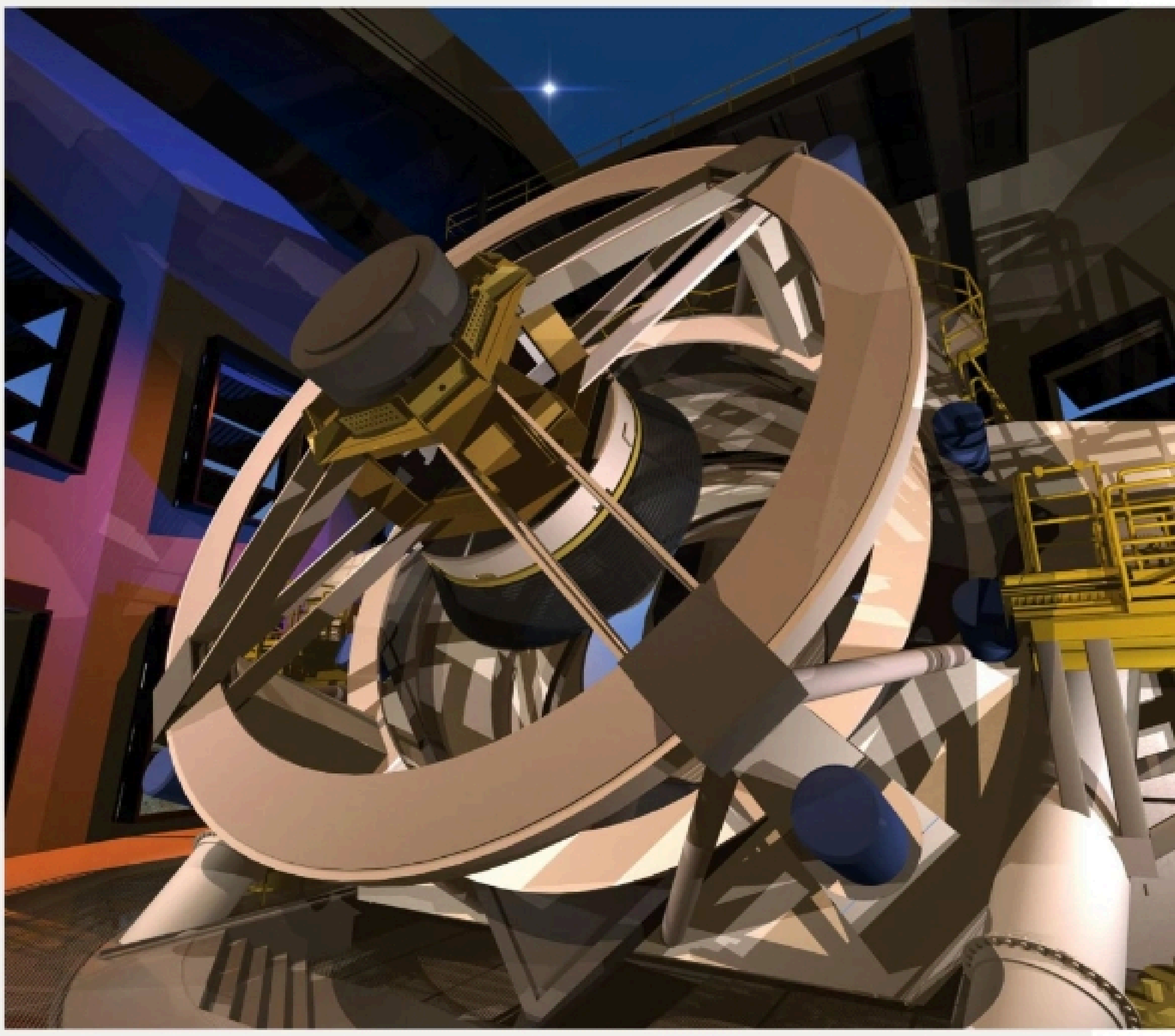
Left: Amateur astronomers have provided important observations of the night sky for centuries

Right: 20 terabytes of data will be captured and stored by the LSST each night

The Crowd and the Cosmos: Adventures of the Zooniverse

Chris Lintott's latest semi-autobiographical book tells a wonderful story of how volunteers have shaped the course of scientific history. With the increase in artificial intelligence and state-of-the-art telescopes, is this soon to end? Chris doesn't think so. In fact, the Zooniverse is needed now more than ever.





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SECRET LIVES OF SPACE'S GREATEST HEROES

These six men and women made groundbreaking contributions to our understanding of the universe, and their stories are often linked in surprising ways

Written by Giles Sparrow

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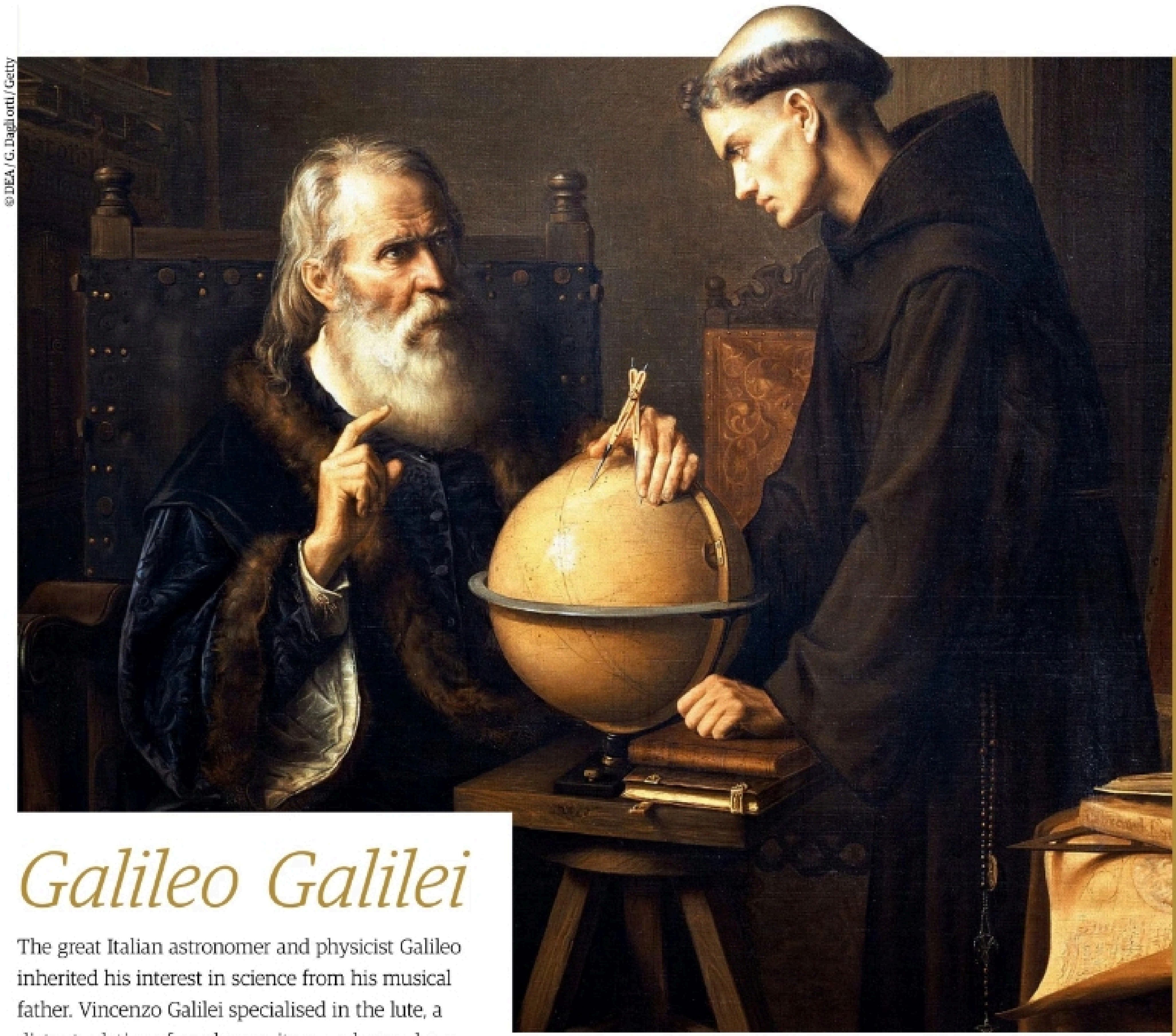

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Above: Galileo clashed with the Catholic Church by siding with Copernicus' heliocentric Solar System

Galileo Galilei

The great Italian astronomer and physicist Galileo inherited his interest in science from his musical father. Vincenzo Galilei specialised in the lute, a distant relative of modern guitars, and was also a musical theorist who used experimentation and mathematics to identify a new law that correctly described the relationship between the tension on a string and its musical pitch. Vincenzo's discoveries helped to inspire his son's mathematical approach to problems of 'natural philosophy' and foreshadowed Galileo's own struggles to overturn outdated views of the world.

At age 17, Galileo became a student in the University at Pisa, training in medicine at his father's suggestion. He made his first great discovery – that a pendulum has a regular period regardless of the width of its oscillations – while watching a swinging lamp in Pisa Cathedral, and had soon turned it into a practical device for measuring a patient's pulse. After persuading his father to let him pursue his interest in mathematics, he became a professor by the age of 25.

Throughout his life, Galileo was perpetually short of cash. His father's death left him responsible for his mother and three younger siblings – and later his own partner and three children. He boosted his income by taking in private students and selling his inventions, and later took a better paid job at Padua in the Republic of Venice. It was here in 1609 that he got word of an amazing new invention from the Netherlands – the telescope.

Galileo immediately set out to make a telescope of his own, using lenses mounted at either end of a card tube. Thanks to his talents for maths and experimentation, he soon found ways of improving on the basic idea. When he showed it to the Venetian rulers, they offered to double his salary and pay handsomely for the instrument itself.

Within a few months, the course of Galileo's life was fatefully changed as he turned his telescope to the sky and made a series of discoveries including mountains on the Moon, countless faint stars and four small moons circling Jupiter. These findings undermined the traditional view that everything in the universe circled Earth – Nicolaus Copernicus, a Polish priest, had suggested the idea of a Sun-centred universe in 1543, but until now there had been no observational evidence to back it up.

Galileo's account of his discoveries in his book *The Starry Messenger* turned him into a scientific celebrity, but from 1613 onwards his arguments in support of the Copernican model put him on a collision course with the Roman Catholic Church. Powerful connections helped to protect him at first, but an argumentative nature got him into repeated trouble, and his 1632 *Dialogue Concerning the Two Chief World Systems* led to a trial before the inquisition and a sentence of house arrest for the rest of his life. Nevertheless, he continued to make important contributions to the foundations of modern physics right up until his death in 1642.

Galileo's planet: Jupiter

Jupiter is the Solar System's largest planet. Its volume is 1,321-times larger than Earth's and its mass is 318 times ours.

It's named after the Roman god Jupiter, the god of sky and thunder.

It's the fourth-brightest object in the sky after the Sun, Moon and Venus.

Jupiter has 53 confirmed moons, its four largest being Io, Europa, Callisto and Ganymede.

The 'King of the Solar System' has faint dusty rings. They weren't discovered until 1979.

The Great Red Spot on Jupiter is a storm that's large enough to engulf the Earth. It's been swirling for at least 300 years.

It has the fastest rotation in the Solar System, completing a spin in less than ten hours – fast enough to cause a bulge at the equator.

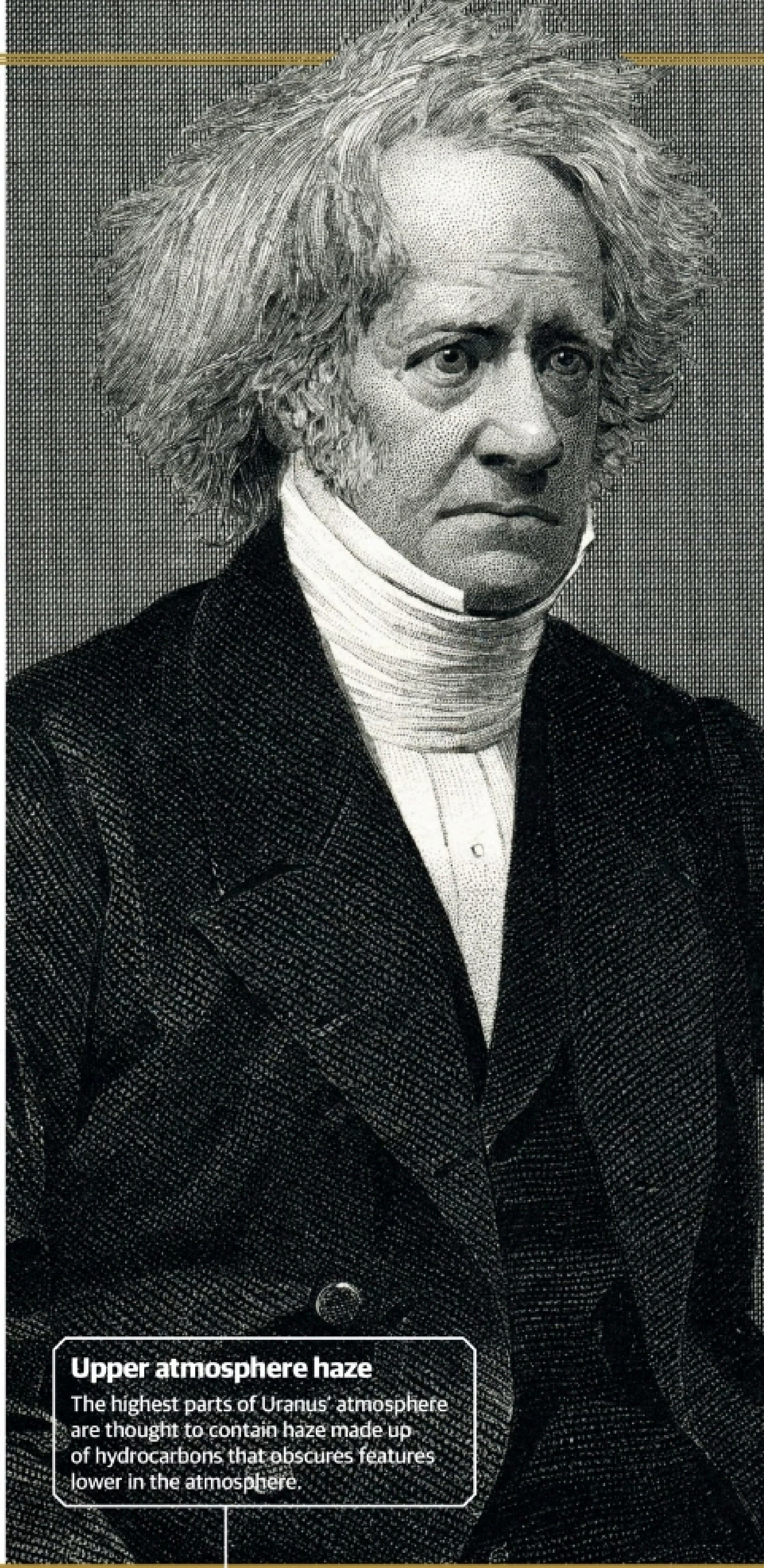
It's difficult to pinpoint when Jupiter was discovered – being visible to the naked eye, records date back to the 7th or 8th century CE.

William Herschel

No one knows quite when William became interested in astronomy, but his sister Caroline's memoirs recall him discussing the night sky with her on their journey to England. Shortly after their arrival, he began building his own telescopes – at first simply by assembling lenses obtained by local glassmakers, but later, as his needs grew more demanding, by casting mirrors and building reflecting telescopes of his own design.

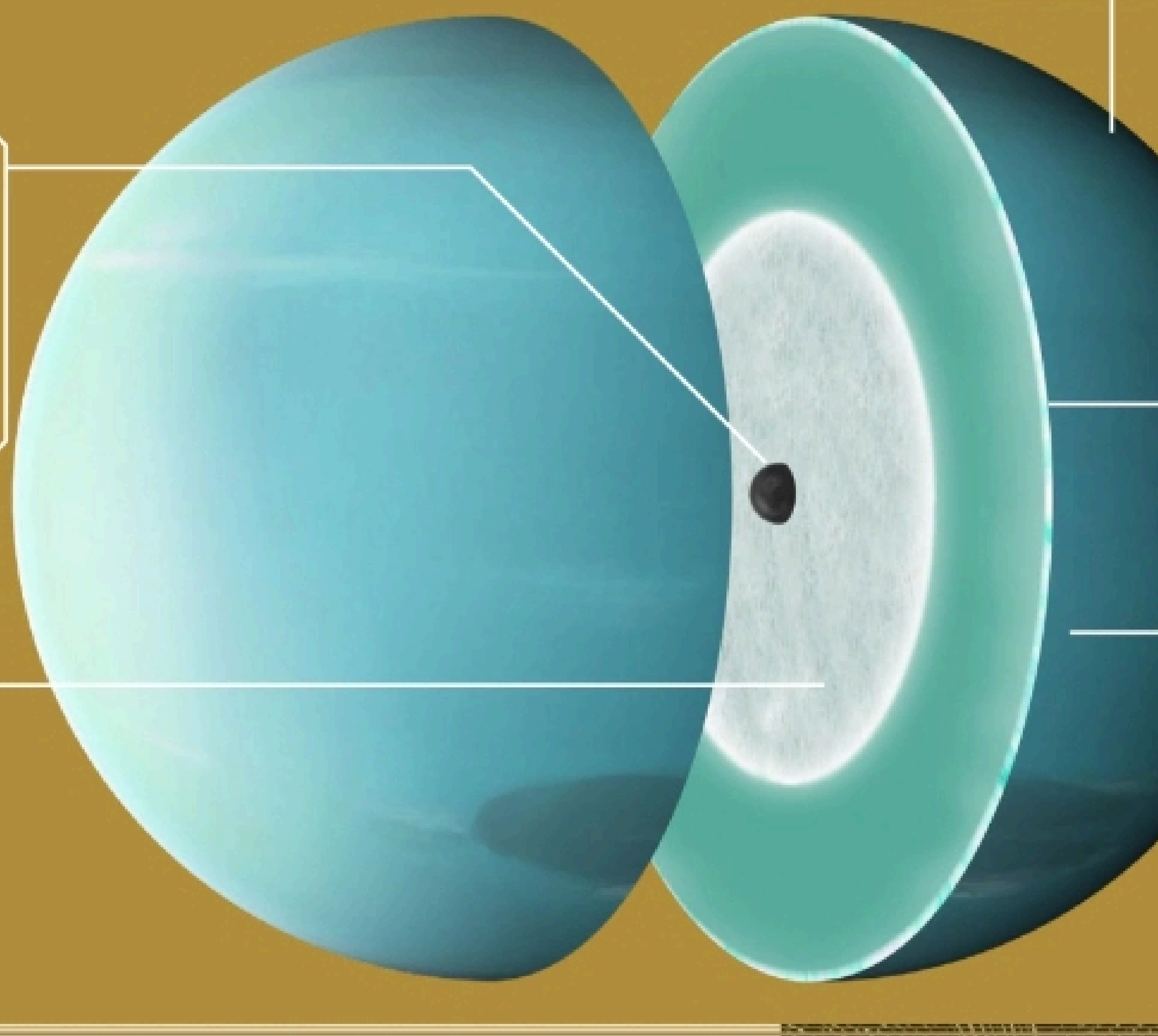
Eventually, William had instruments that were fit for his plans – not just to observe the night sky, but to carry out detailed surveys in search of comets and other undiscovered objects. His telescopes were the best of their age, and his reputation soon began to spread. His first project involved a systematic catalogue of closely spaced stars, with William spending all his available nights at the eyepiece and Caroline making careful notes. At the time most people assumed that stars were randomly scattered through space, but the discovery of numerous close pairs convinced him otherwise. There were too many to be accounted for by chance alignments, so some of them at least must be paired binary stars in orbit around each other.

In March 1781, William spotted the planet now called Uranus. When he first saw the spherical bluish blob in the constellation of Taurus, he assumed it was a comet – it was Astronomer Royal Nevil Maskelyne who began to wonder whether the unusually solid-looking object might be a planet beyond Saturn. A few months later, continued tracking of the object's movement confirmed that it was indeed a remote planet. Herschel suggested naming it George's Star – after King George III – and the king returned the honour by naming William his personal astronomer and granting him a salary of £200 on condition that he moved to Windsor, with an additional £50 for Caroline to work as his assistant. The Herschels, both brother and sister, abandoned their musical careers to become some of Europe's first professional scientists. They would go on to make countless other discoveries.



Right: Herschel was trained as a musician and joined the army at just 14 years of age

Inside Uranus



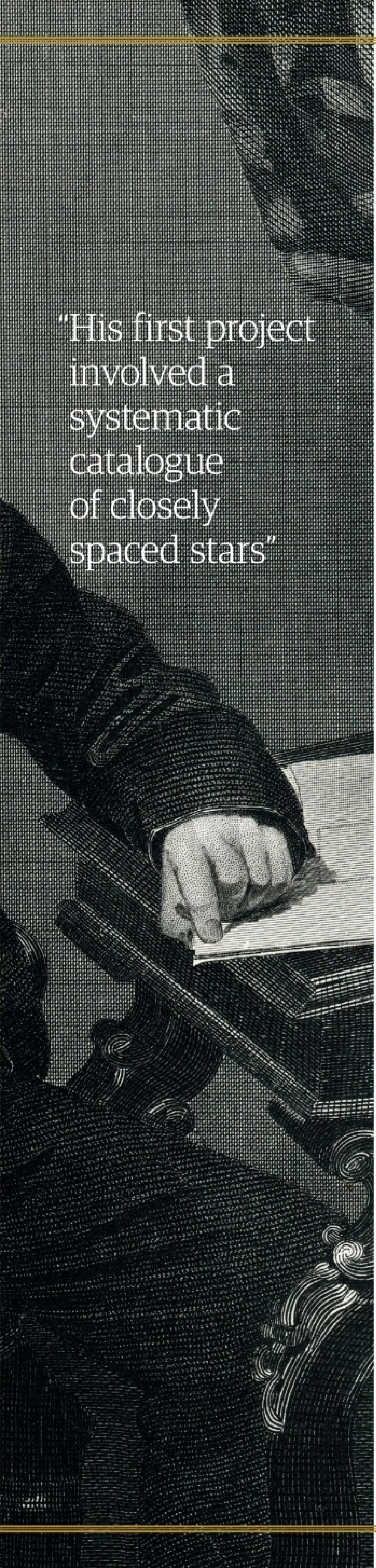
Upper atmosphere haze
The highest parts of Uranus' atmosphere are thought to contain haze made up of hydrocarbons that obscures features lower in the atmosphere.

Planetary core
Uranus' core extends to about a fifth of the planet's full diameter, and is made of rock, ice and silica. Its temperature is thought to be around 5,000°C (9,032°F).

Icy mantle
This isn't ice as we know it. Uranus' mantle is made up of a hot, dense fluid scientists refer to as a water-ammonia ocean.

Potential heat-trapping layer
Scientists have not confirmed the existence of a layer around Uranus' ice layer trapping heat and making it appear cooler, but one could have formed during a giant impact.

Atmosphere
Uranus looks bluish-green through a telescope thanks to the methane in its atmosphere. It also contains hydrogen, helium, acetylene and other hydrocarbons.


"His first project involved a systematic catalogue of closely spaced stars"

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Henrietta Swan Leavitt

Several remarkable female astronomers played a key role in establishing our understanding of the stars in the late-19th and early 20th centuries, and Henrietta Swan Leavitt was arguably the most important of them all, laying the foundations for a revolution in our view of the entire universe.

Leavitt was born in 1868 to a well-off Massachusetts family. After displaying an early academic talent, she studied at Oberlin College in Ohio and Harvard University's Society for the Collegiate Instruction of Women (later Radcliffe College). Although she showed a talent for mathematics, she did not take a course in astronomy until her fourth year of university.

After graduating in 1892 – without a degree since at the time they were not awarded to women – Henrietta pursued her newfound interest in the heavens by applying to work at Harvard College Observatory. Here, astronomer Edward Charles Pickering was assembling a team of women to catalogue and analyse data being gathered by the first photographic survey of the sky. Work was often published under Pickering's name with little acknowledgement of the women behind the scenes. Nevertheless, the so-called 'Harvard Computers' would make huge contributions to our understanding of the structure and evolution of stars.

Henrietta's particular speciality was the analysis of variable stars – measuring how their brightness fluctuated between photographic plates taken on different nights and trying to identify patterns. However, her career was somewhat intermittent, with frequent breaks for travel, family responsibilities and for the good of her delicate health and overstrained eyesight.

It was in 1904 that she turned her attention to new plates sent from the observatory's Southern Hemisphere outpost at Arequipa in Peru. These images showed the Small Magellanic Cloud (SMC) – a crowded clump of stars near the southern Milky Way. Here, Leavitt found and analysed more than 1,770 new variable stars. Among them, she spotted 16 with a distinctive cycle of changing light that suggested they were related.

In a 1908 paper reporting her discoveries, she noted that among these stars, the brighter ones had longer periods. Because stars in the cloud could be assumed to lie at the same distance from Earth, their apparent brightness in photographs would be a reflection of their true physical brightness, or 'luminosity', something that wasn't true for stars randomly scattered elsewhere in the sky.

After identifying several more stars to conclusively prove the link, Henrietta published her 'period-luminosity relationship' in a paper of 1912. The implications were huge: astronomers soon realised that Henrietta's stars were of a familiar type known as Cepheids, and this meant that the relative distances of similar stars elsewhere in the sky could be worked out.

© Alamy

Henrietta succumbed to stomach cancer in 1921, before the full implications of her work became clear. Just four years later, Edwin Hubble found and measured Cepheid variables embedded in some of the mysterious 'spiral nebulae' that dotted the sky. He showed that they were fainter even than those in the SMC, and conclusively proved that the nebulae are actually galaxies far beyond the Milky Way. Today, Cepheids remain a vital rung on the cosmic-distance ladder used to measure the scale of the universe.

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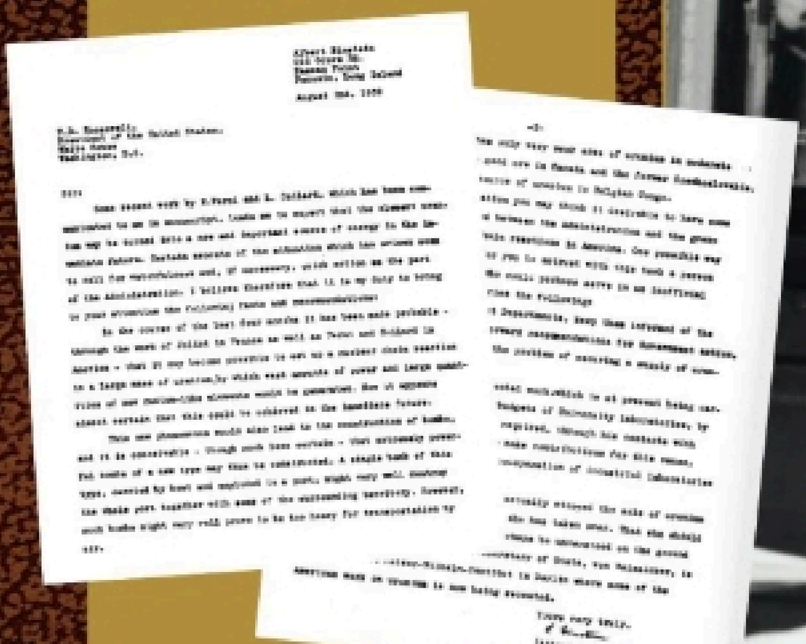
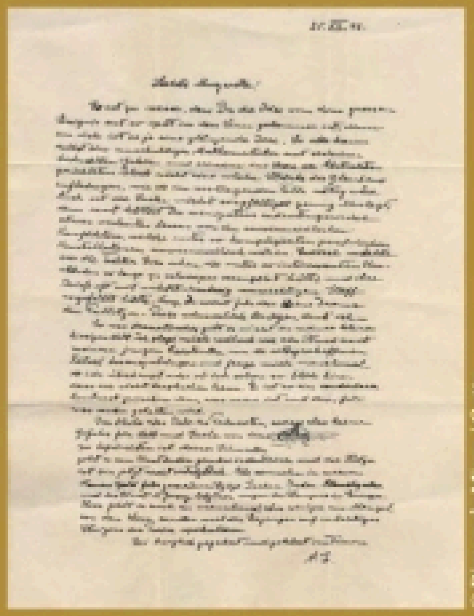
Einstein's greatest letters



A letter sent to U.S. President Franklin D. Roosevelt, signed by Albert Einstein, details uranium as a new and important source of energy in the "immediate future"



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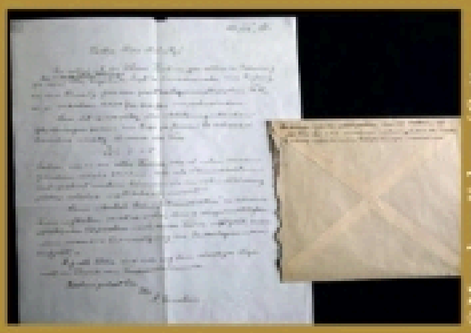
Albert Einstein pens a romantic letter to Russian spy Margarita Konenkova



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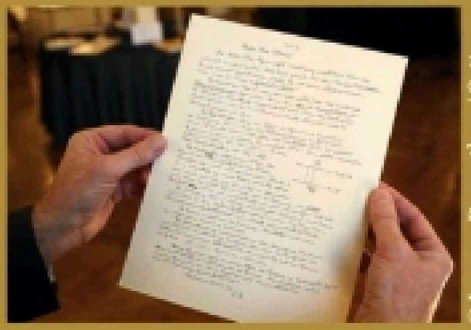
This signed letter dates back to 1928 and concerns the formalisation of the 'Third Stage of the Theory of Relativity'



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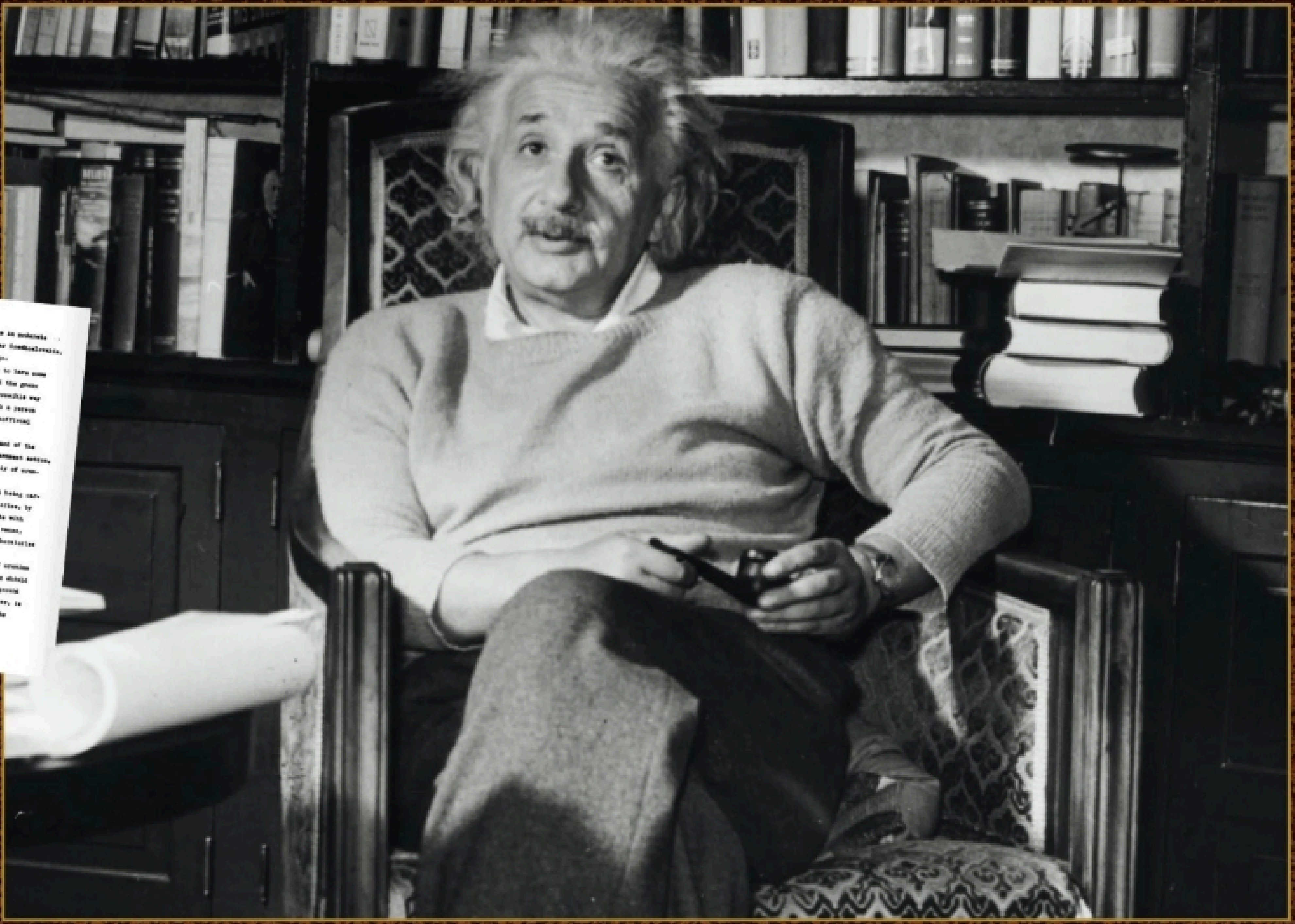
A letter signed by Albert Einstein to Ernst Gabor Strauss about the unified field theory



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Albert Einstein

Above: Einstein is best known for his work surrounding the speed of light and relativity

Right: Eddington made crucial observations of stars around the Sun during a total eclipse

Born in Ulm, southern Germany, in 1879, Albert Einstein would become the most famous physicist of the 20th century, introducing revolutionary ideas that transformed all of science – and astronomy in particular.

Einstein showed his remarkable talents from an early age, reading widely and mastering tricky mathematical fields such as algebra and Euclidean geometry before he was a teenager. However, the young Albert grew restless with the dull curriculum and regimented teaching methods, and eventually ditched school entirely, completing his education in Switzerland some time later.

After graduating from the Federal Polytechnic School in Zürich, Einstein was frustrated in his search for a teaching post of his own. Eventually, after taking Swiss citizenship – also a way of avoiding German military service – he found employment at the Bern patent office, in a job that left him with plenty of spare time to work on his PhD and consider the questions that he was really interested in.

In 1905, Einstein stepped into the limelight with the publication of not one, but four groundbreaking scientific papers. One provided long-sought-after direct proof of the existence of atoms. Another laid the foundations for what would become known as quantum physics, but it was the other two that transformed our view of the universe itself.

Einstein's breakthrough came from confronting questions about the speed of light, which always seemed to be the same regardless of the relative motions of the light source and the measuring device. Physicists had put forward many possible explanations for this troubling phenomenon, but all relied on it being a kind of illusion, and none of them were satisfactory.

Einstein, however, dared to ask if the speed of light really is constant, regardless of relative motion. He showed that the consequences for everyday life would be unnoticeable, but that in 'relativistic' situations, with an observer and an object or light source moving at near-light speed relative to each other, strange effects would occur. From the observer's point of view, objects at near light speed appear to become shorter and to experience time more slowly.

Further consideration led Einstein to conclude that accelerating objects already at relativistic

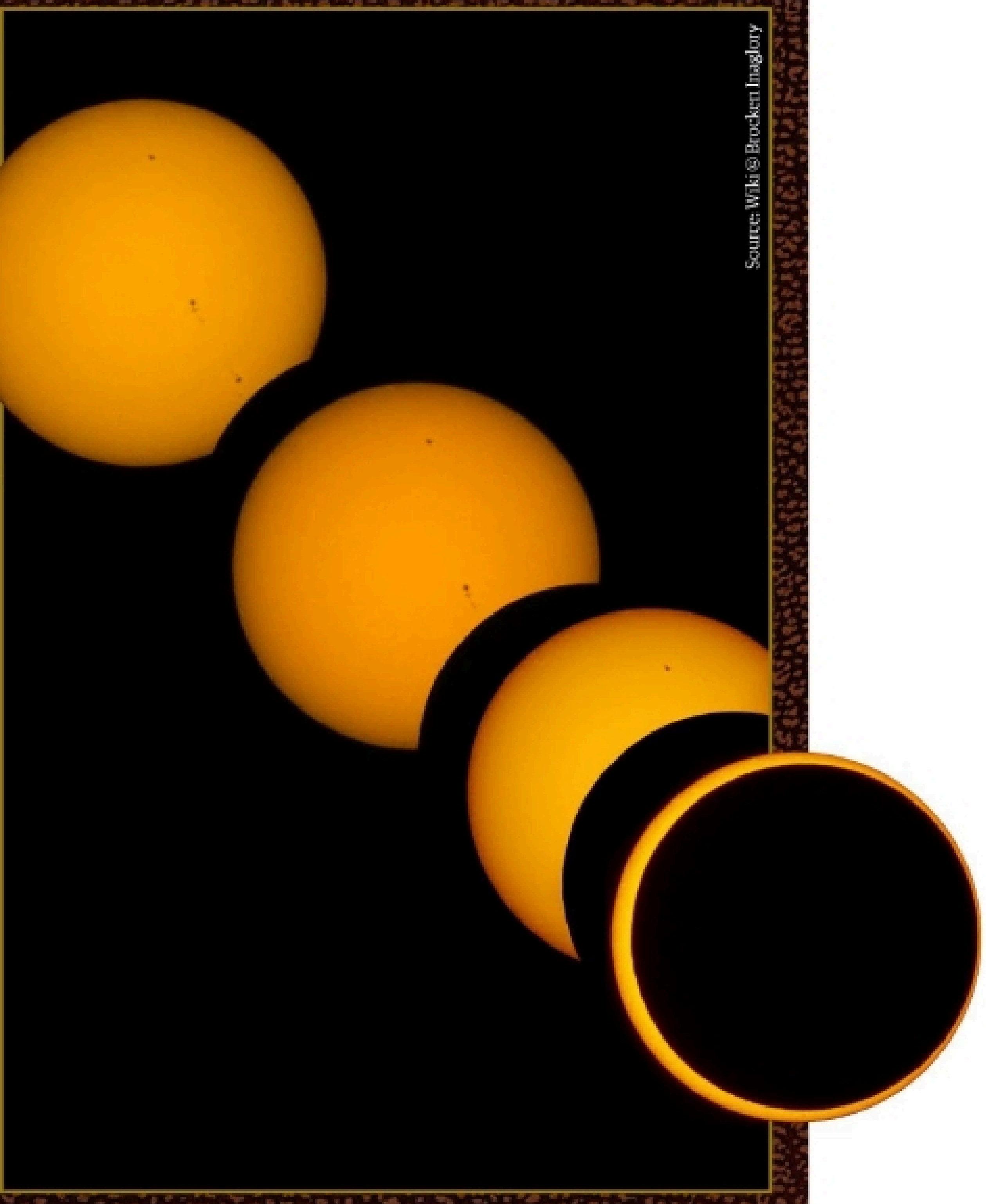
> "Einstein showed his remarkable talents from an early age, mastering tricky mathematical fields"

speeds will tend to increase their mass rather than their speed - since the speed of light itself is unreachable - and this led in turn to the famous equation $E=mc^2$.

Einstein's ideas were hugely influential, but Albert himself was already pondering the next big question. So far he had only formulated a 'special theory of relativity' where the observer and object moved at high relative speed, but did not accelerate or decelerate. He now realised that acceleration was effectively the same as being in a gravitational field, so a description of 'general relativity' would also automatically be a description of gravity itself.

Einstein's theory of general relativity, when it emerged, showed that the presence of large masses can have effects similar to those seen in special relativity, distorting our measurements of time and space. However, its publication in 1916, as Europe tore itself apart in the First World War, meant it was widely overlooked.

It was only in 1919, following the return of peace, that astronomer Sir Arthur Eddington was able to journey to Africa and make crucial observations of stars around the Sun during a solar eclipse. These revealed the effect we now call gravitational lensing in the form of a slight distortion in the measured positions of the stars as light is deflected due to the Sun's distortion of nearby space and time. Einstein was proved right, opening the way for a new era in physics, and eventually for powerful new astronomical techniques that make use of his discoveries and predictions.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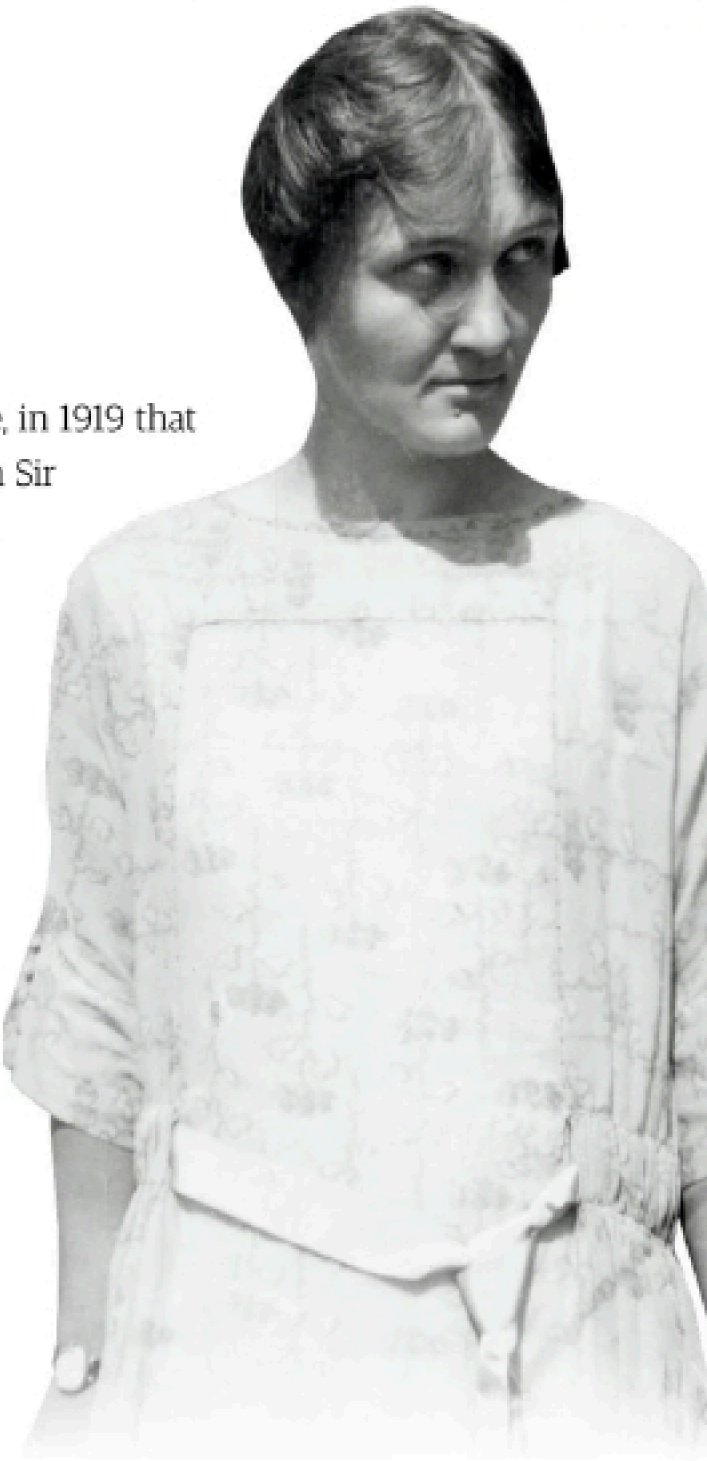
Cecilia Payne-Gaposchkin



It was while studying at Newnham College, Cambridge, in 1919 that her interest in astronomy was ignited by a lecture from Sir Arthur Eddington on Einstein's new science of general relativity. Determined to follow her newfound passion after leaving Cambridge, she applied to Harvard College Observatory. Alongside images of the sky, the Observatory's catalogue also included the spectra of countless stars, made by spreading out starlight according to its wavelength and capturing it on photographic plates. These rainbow-like bands were usually crossed by a variety of dark 'absorption lines' - chemical fingerprints created by the light-absorbing properties of various elements somehow associated with the stars themselves. The goal of her PhD thesis would be to explain exactly how.

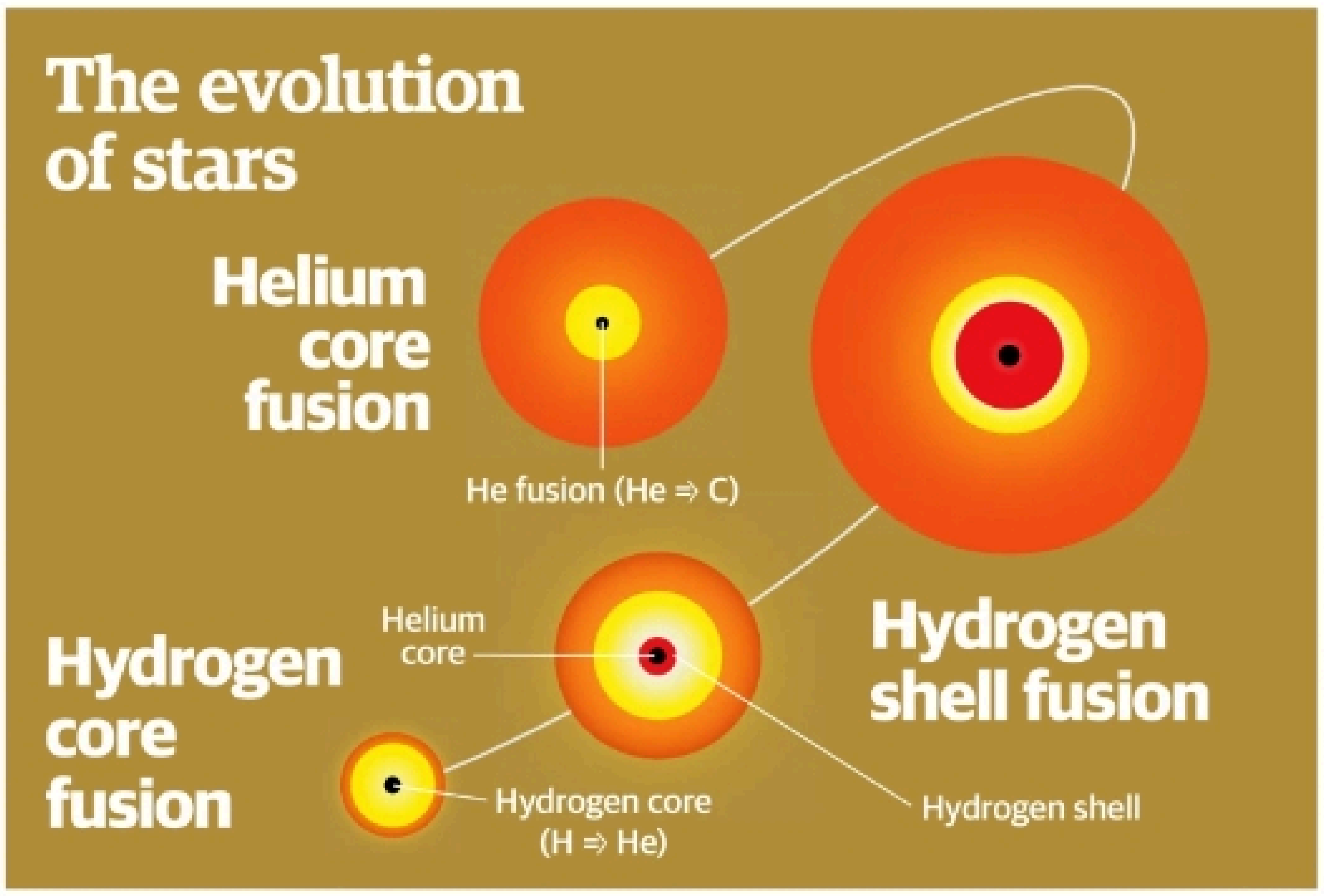
One of the most puzzling aspects of stellar spectra was the huge variety in the strength and number of their absorption lines, implying great variation in the elements they contained - by proper application of the equation, Cecilia was able to show that most of this variety was due to differences in the surface temperature of the stars, not to their composition. Higher temperatures strip away more of the electrons from around atoms in a star's atmosphere, leaving 'ions' with increasingly positive electric charges that interact differently with light escaping from the star's surface.

Applying these principles to the atmospheres of various stars, Payne showed that they contained similar amounts of relatively heavy elements such as silicon, carbon and oxygen to those found on Earth. But there was a troubling discrepancy when it came to the lightest elements: helium and especially hydrogen seemed to be vastly more abundant in the stars than they are on Earth.

Throughout a long and distinguished career spent entirely at Harvard, Cecilia was able to see the fruits of her breakthrough in understanding the composition of stars. Understanding that they are predominantly made of hydrogen is the key to understanding the fuel source that powers them, the conditions inside them and the various tracks along which they can evolve during their lifetimes.

Above: Payne anaylsed the spectra of stars and unlocked the secrets of stellar composition

The evolution of stars



Source: Wikipedia © Smithsonian Institution

Katherine Johnson

Katherine grew up in the southern United States at a time when racial segregation was commonplace and opportunities for African Americans were in short supply. In 1952, Katherine learned that the National Advisory Committee for Aeronautics (NACA) was looking to hire mathematicians. At first she was assigned to the group of black women 'computers' who did the number-crunching to analyse data gathered from NACA's research aircraft. Her particular talent was soon recognised, however, with a temporary posting within an all-male, all-white team at the Flight Research Division that became permanent.

After the surprise launch of the Soviet Union's Sputnik satellite in 1957, chaotic early US attempts to play 'catch up' culminated in a wholesale reorganisation of NACA to form the nucleus of the current NASA. Racial and gender segregation were done away with, while the Flight Research Division was renamed the Space Task Group and was charged with putting American astronauts into orbit ahead of the Soviets. Katharine was therefore in the right place at the right time to play a key role in the early US space effort. As well as working on Alan Shepard's Freedom 7 suborbital flight in 1961, she co-authored work on the precise placement of satellites in particular orbits and the relationship between a spacecraft's re-entry point and its landing site.

Despite machine-based calculation fast becoming the norm at NASA, the early 'Mercury 7' astronauts were reluctant to put their lives entirely in the hands of technology, and John Glenn famously asked for Katherine to manually recheck the calculations before the launch of his Friendship 7 spacecraft on the first US orbital mission.

Johnson continued to work at NASA until her retirement in 1986. She considered her proudest achievement to be the calculations needed to sync the Apollo Lunar Module with the orbiting Command Module. She also helped devise a method of 'navigation by the stars' that allowed the astronauts of the crippled Apollo 13 spacecraft to time the precise engine burn needed to return them safely to Earth. In 2015, she was awarded the Presidential Medal of Freedom by US President Barack Obama, while the following year, her story, along with those of other black American women at Langley, was chronicled in Margot Lee Shetterly's book *Hidden Figures*.

Johnson's Apollo 11 code

74

Memory (ROM) of the Apollo guidance computer, in kilobytes

1202

The first of several 1202 and 1201 computer alarms began to sound when Armstrong ignited the descent engine on the lunar lander

9

Early versions of the Sony Walkman portable cassette recorders were flown on the Apollo missions

6.7

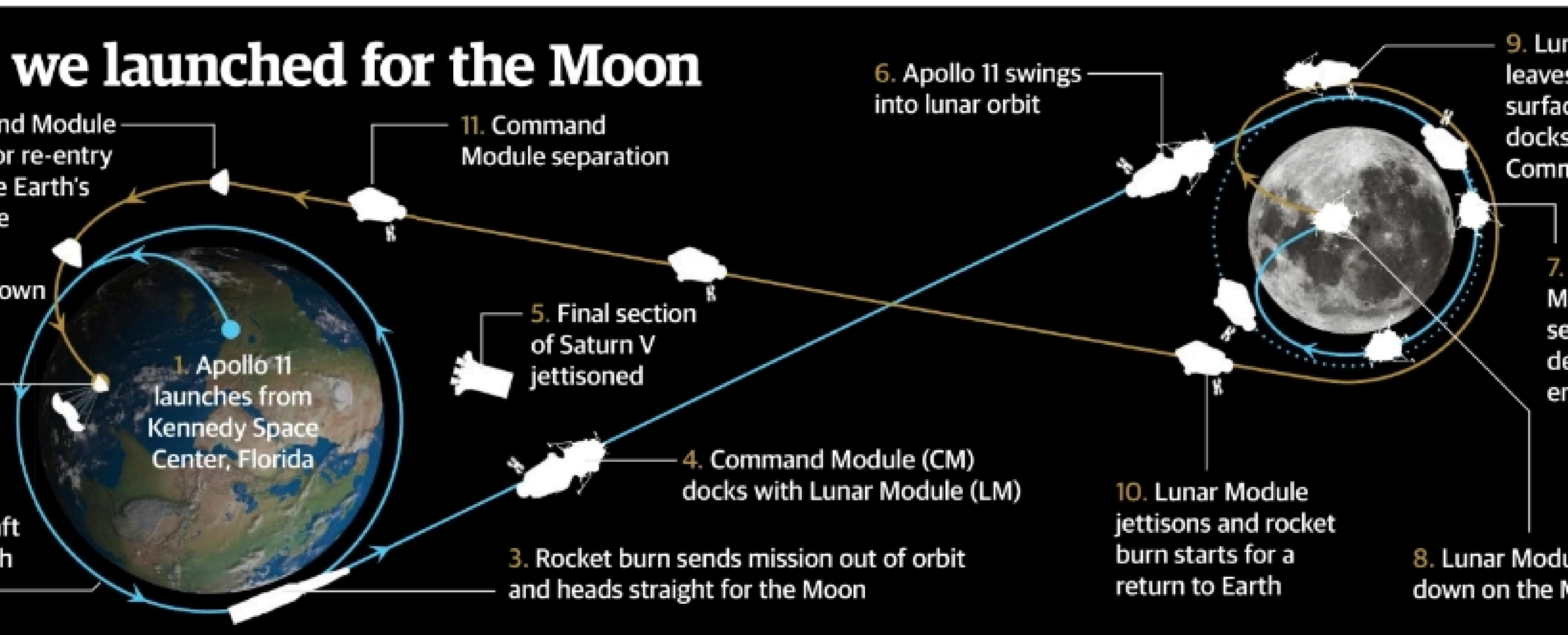
The diameter of the Saturn V computer in metres

36

Weight of satellites launched by Apollo in kilograms

©NASA

How we launched for the Moon


1. Apollo 11 launches from Kennedy Space Center, Florida
2. Spacecraft enters Earth orbit
3. Rocket burn sends mission out of orbit and heads straight for the Moon
4. Command Module (CM) docks with Lunar Module (LM)
5. Final section of Saturn V jettisoned
6. Apollo 11 swings into lunar orbit
7. Lunar Module separation descent engine ignites
8. Lunar Module touches down on the Moon
9. Lunar Module leaves Moon's surface and docks with the Command Module
10. Lunar Module jettisons and rocket burn starts for a return to Earth
11. Command Module separation
12. Command Module positions for re-entry through the Earth's atmosphere
13. Splashdown in Pacific Ocean

APOLLO 11
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SPECIAL EDITION SPACE PENS

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Matte Black Bullet Space Pen
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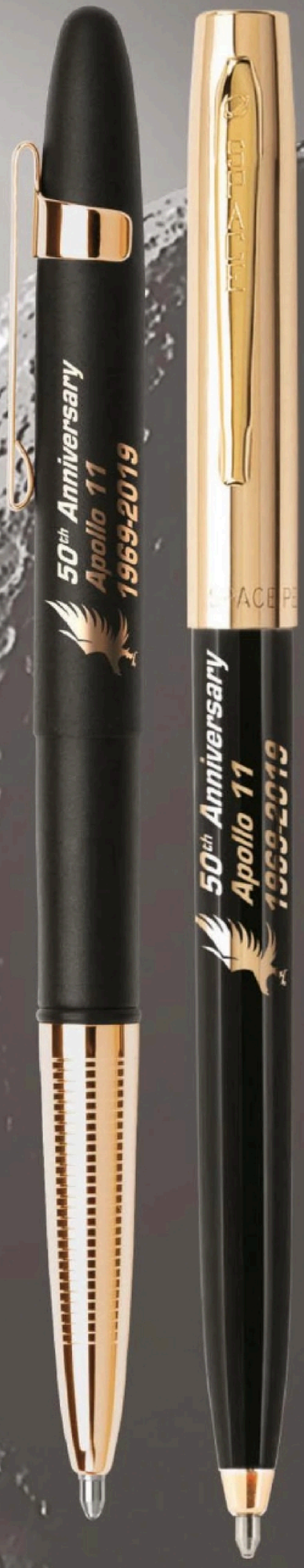
When astronauts began to explore the reaches of outer space, Paul Fisher realized that there was no existing pen which could perform in its freezing cold, boiling hot vacuum. Countless experiments and a common-sense approach resulted in the invention of the sealed and pressurized ink cartridge and in 1967, after 18 months of rigorous testing by NASA, the Fisher Space Pen® was selected for use by the astronauts. It is still used today on all manned space flights.

Matte Black Bullet Space Pen
Moonscape Box



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The main challenge facing the Solar Orbiter mission is having to guard against the rays of the Sun, so engineers have specially designed a black heat shield

© ESA

USER MANUAL

Solar Orbiter

Early 2020 will see the launch of an ambitious mission to observe the poles of the Sun for the first time ever

THE SPECS

Launch: February 2020

Launch site: Cape Canaveral Air Force Station, Florida

Launch rocket: Atlas V 411

Target: Sun

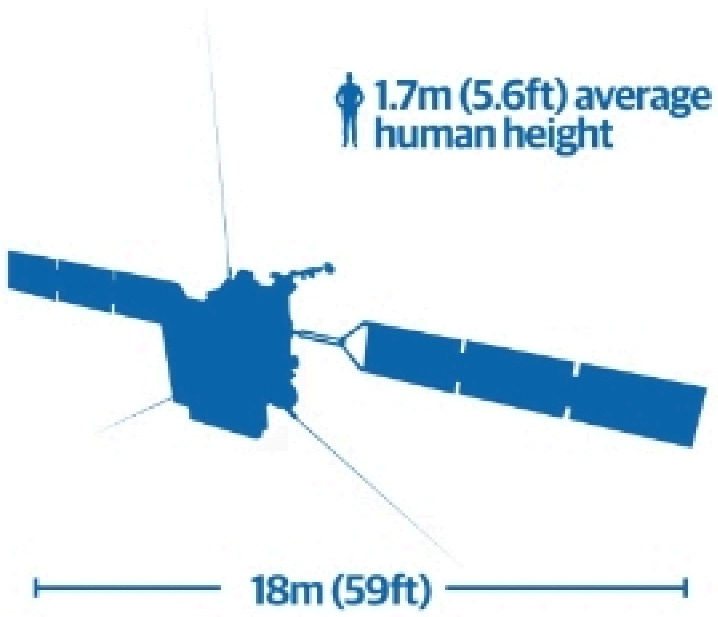
Operator: ESA/NASA

Programme cost: £520 million ($672 million)

Components: Multiple

Height: Three metres (9.8 feet)

Diameter: 18 metres (59 feet)



In February 2020, the European Space Agency's (ESA) highly anticipated Solar Orbiter will launch from Cape Canaveral in Florida on top of an Atlas V rocket. Although this mission is led by the ESA, it has had strong contributions from NASA, including the launch site and rocket. This is one of the missions that constitutes the ESA's Cosmic Vision programme, and will investigate the only star in our Solar System, the Sun. Not only is it equipped with ten state-of-the-art instruments – designed to investigate everything from coronal mass ejections (CMEs) to the solar wind – it will also conduct the first-ever observations of the solar poles.

The cosmic generator that sits at the centre of the Solar System is not only surrounded by everything from the tiniest asteroids to gas giants several times larger than Earth, it is also heavily shrouded in mystery. One huge mystery that has had solar scientists scratching their heads for years is the Sun's corona. This outer region can be as much as 300-times hotter than the 'surface' of the Sun, called the photosphere. It is comparable to taking your hand away from a fire and feeling it heat up. It is a complete cosmic conundrum.

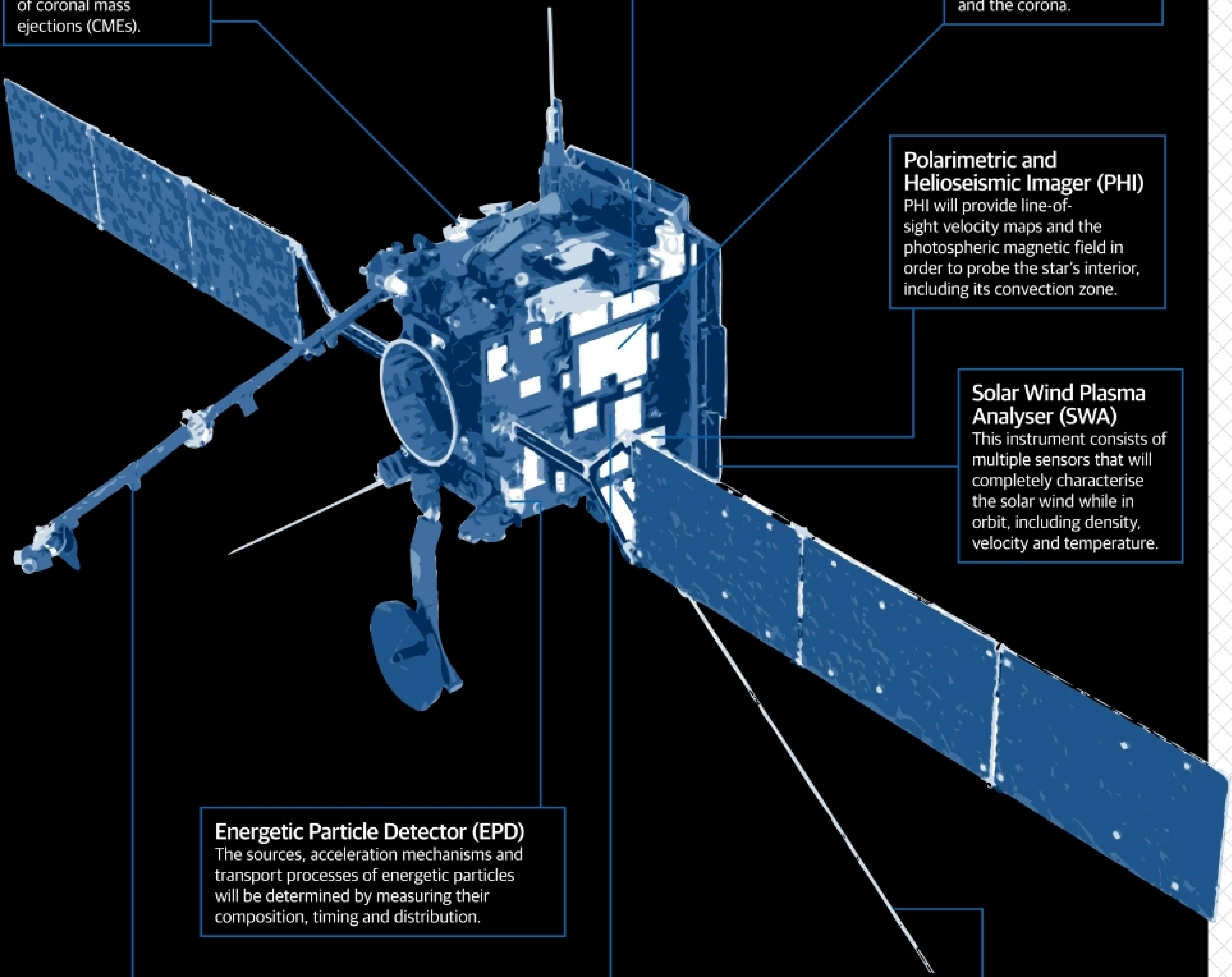
Unfortunately, because this ball of plasma is so powerful and unpredictable – capable of producing events that could potentially harm us on Earth, let alone a nearby spacecraft – it is very difficult to investigate up close. Several missions have tried to understand the beast, with honourable mentions to other NASA/ESA missions Ulysses and the Solar and Heliospheric Observatory (SOHO), but even they were not enough. There is still so much mystery surrounding the Sun's heliosphere, the solar activity that is the driving force for solar wind and CMEs and their variability. Now the ESA is launching this new-and-improved investigator to probe the Sun in unprecedented detail.

The Solar Orbiter, which is abbreviated as 'SolO', will provide both remote and in-situ observations courtesy of an extremely elliptical orbit. This elliptical orbit will be created after a series of gravity-assist manoeuvres of Earth and Venus, taking the spacecraft to an aphelion – the distance at the object's farthest point – of 170 million kilometres (105 million miles) and a perihelion – its closest point – of 42 million kilometres (26 million miles).

> "Not only is it equipped with state-of-the-art instruments, it will also conduct the first-ever observations of the solar poles"

Anatomy of a Sun skimmer

These instruments will probe the Sun and its environment up close, far away and from a whole load of angles



Heliospheric Imager (SoloHI)
By imaging quasi-steady flow and solar wind disturbances, SoloHI will be able to provide pinpoint measurements of coronal mass ejections (CMEs).

Spectrometer Telescope for Imaging X-rays (STIX)
Imagery and spectroscopy of the Sun's X-ray emissions will provide quantitative data about accelerated particles and thermal plasma, mostly associated with flares and microflares.

Extreme Ultraviolet Imager (EUI)
EUI will image the star's layers outside the photosphere in order to determine the link between the solar surface and the corona.

Polarimetric and Helioseismic Imager (PHI)
PHI will provide line-of-sight velocity maps and the photospheric magnetic field in order to probe the star's interior, including its convection zone.

Solar Wind Plasma Analyser (SWA)
This instrument consists of multiple sensors that will completely characterise the solar wind while in orbit, including density, velocity and temperature.

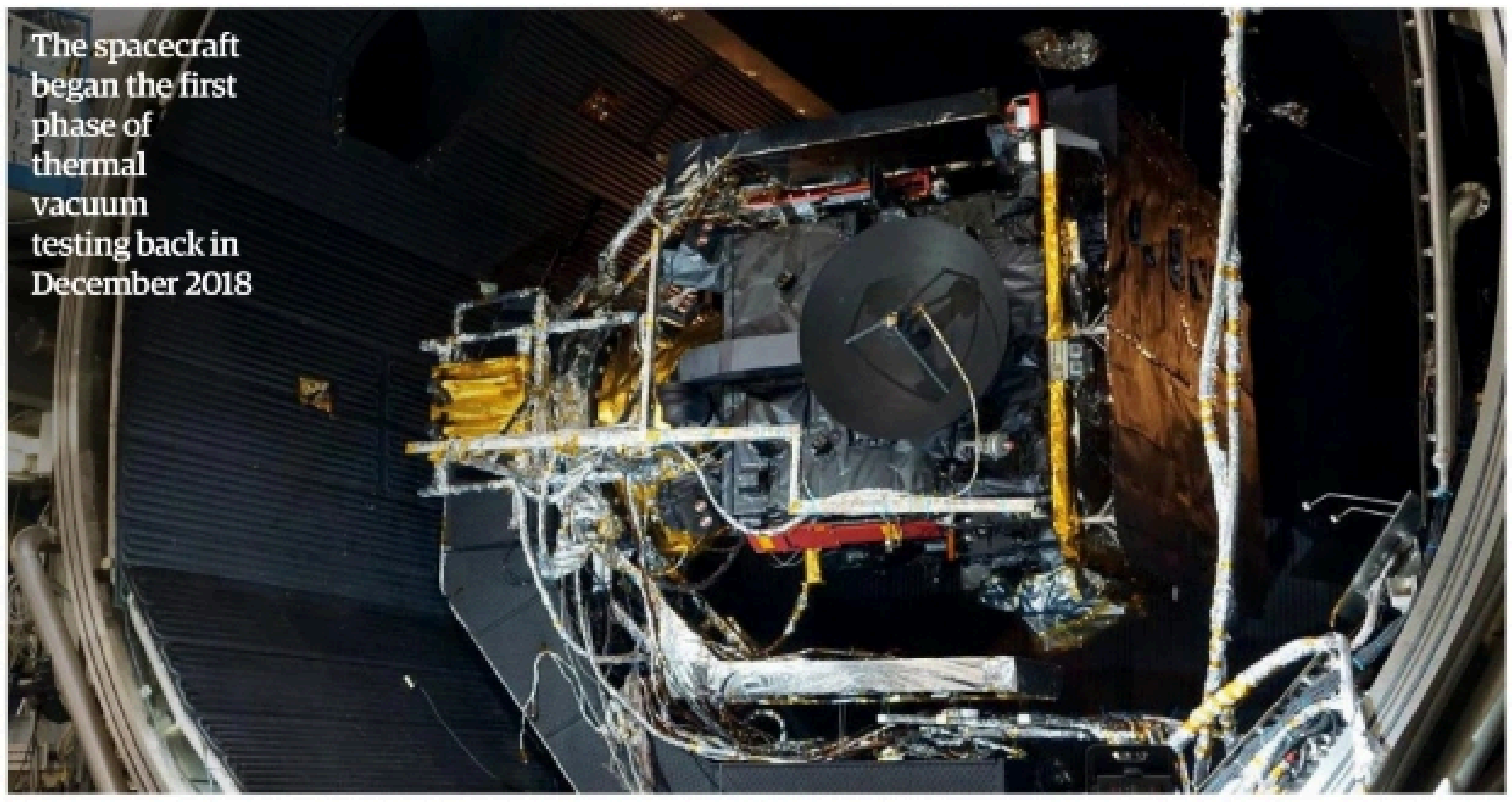
Energetic Particle Detector (EPD)
The sources, acceleration mechanisms and transport processes of energetic particles will be determined by measuring their composition, timing and distribution.

Magnetometer (MAG)
The magnetometer will provide high-precision, in-situ measurements of the heliosphere magnetic field and how it evolves in a solar cycle.

Coronagraph (Metis)
This will provide images of the corona in different wavelengths – such as visible, ultraviolet and extreme-ultraviolet – simultaneously.

Radio and Plasma Wave analyser (RPW)
This will offer both in-situ and remote observations of magnetic and electric fields. This will hopefully reveal important properties about the solar wind.

© Adrian Mann



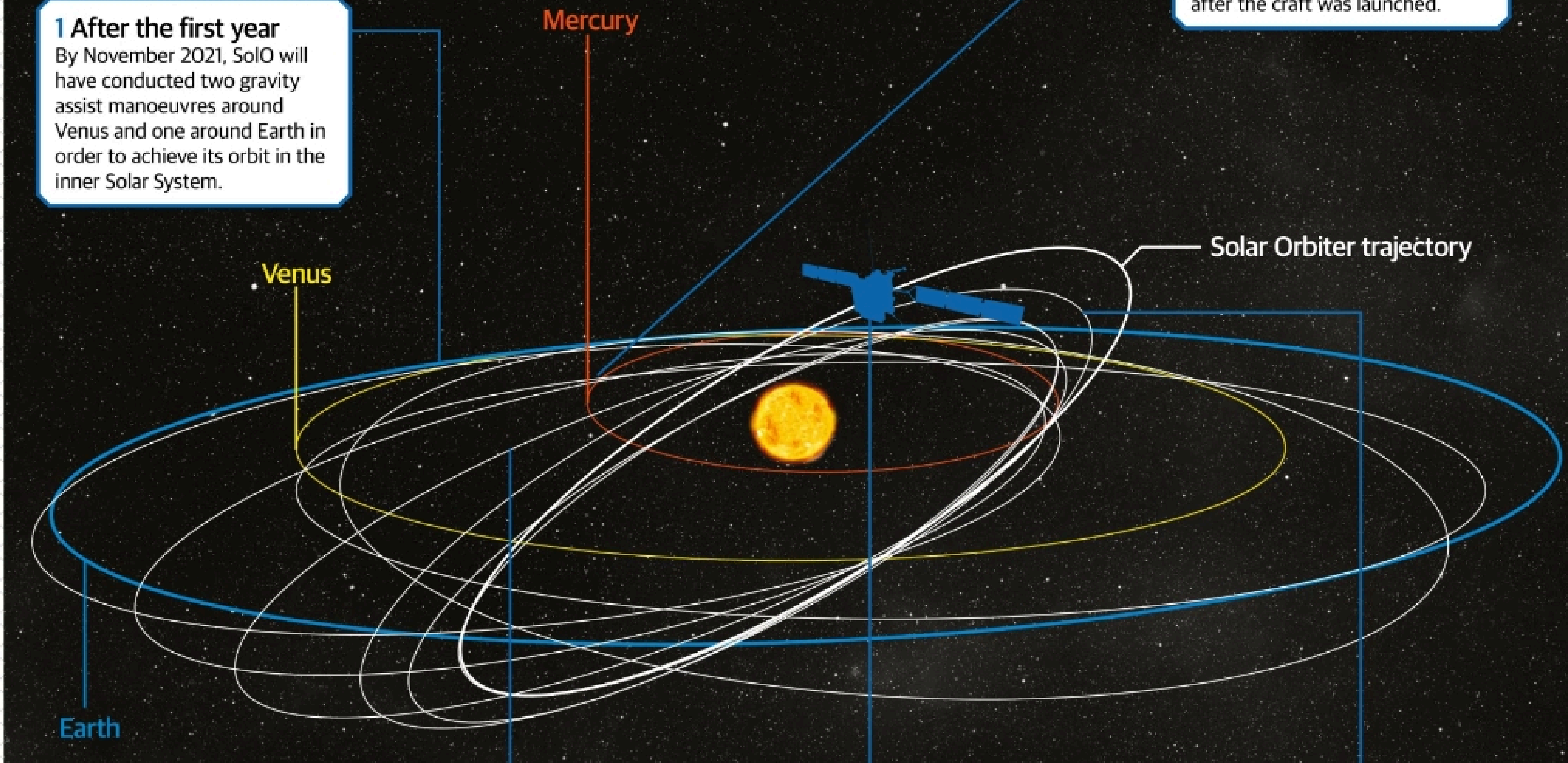
The spacecraft began the first phase of thermal vacuum testing back in December 2018

© ESA

At its perihelion the Solar Orbiter will be a third closer to the Sun than Earth is and will experience solar heating 13-times greater than any satellite currently in orbit around the blue marble we call our home planet. This presents engineers with the difficult task of having to protect the entire spacecraft against the intense rays of the Sun. Engineers have devised a series of radiators, multi-insulating layers and a black heat shield which is capable of withstanding temperatures up to 500 degrees Celsius (932 degrees Fahrenheit) as the craft makes a close approach every six months.

During the seven-year nominal duration of the mission, every year or so the spacecraft will use Venus for a gravity assist that will gradually increase its orbital inclination. It will separate from the relatively flat plane in which the planets orbit the Sun and will begin transitioning to an angle

How the Solar Orbiter will observe the Sun's poles



1 After the first year
By November 2021, SolO will have conducted two gravity assist manoeuvres around Venus and one around Earth in order to achieve its orbit in the inner Solar System.

2 Two years later
The first Venus gravity assist to provide inclination will be in September 2022, over two years after the craft was launched.

3 Five years later
In 2025 SolO will perform its fourth flyby of Venus in order to take its inclination up to 17 degrees. This is a similar inclination to Pluto's orbit.

4 Seven years later
Once the nominal mission duration is completed, which is seven years after launch, the spacecraft will have reached an inclination of 25 degrees.

5 Ten years later
If the mission enters its extended mission duration of ten years, Venus will continue to catapult the spacecraft to an inclination of 34 degrees.

that will allow it to observe the poles of the Sun. This will continue until it reaches a 25-degree inclination after the seven years. If the spacecraft is still operating and capable of performing further science, the SolO team will shift it to 34 degrees over the following three years using a series of Venus gravity assists. From this angled vantage point scientists could have a better chance at understanding the solar dynamo – the physical process that produces the Sun's magnetic field – and how this magnetic field swaps poles every 11 years. This pole reversal causes the solar cycles, which determine the level of solar activity.

In August 2018 NASA launched its Parker Solar Probe, which is trying to accomplish a similar feat. This spacecraft is also getting up close to the Sun, but much closer. This mission is diving into the Sun's corona. At its closest approach the Parker Solar Probe will be six-times closer to the Sun than SolO will ever be. However, the Parker Solar Probe will not be swooping over the star's poles. This provides an interesting and potentially very fruitful opportunity for scientists to co-ordinate observations with the two missions in an attempt to truly understand the Sun's corona.

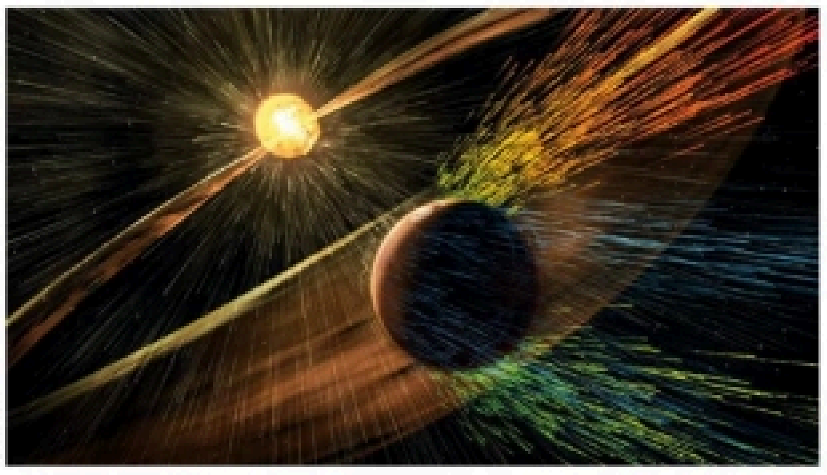
> "It will transition to an angle that will allow it to observe the poles"

TOP TECH

Radio and Plasma Wave analyser (RPW)

The uniqueness of this instrument is that it can provide remote and in-situ observations, so when SolO orbits the Sun every six months, constantly shifting between closer than Mercury and farther away than Earth, RPW can gain valuable data no matter where it sits.

Using a series of antennae and sensors, this instrument will provide high-resolution data of the solar magnetic and electric fields. This investigation will help study the solar wind that permeates throughout the Solar System and poses a potential threat to Earth – frying the electronics of satellites in low-Earth orbit and astronauts on board the International Space Station.



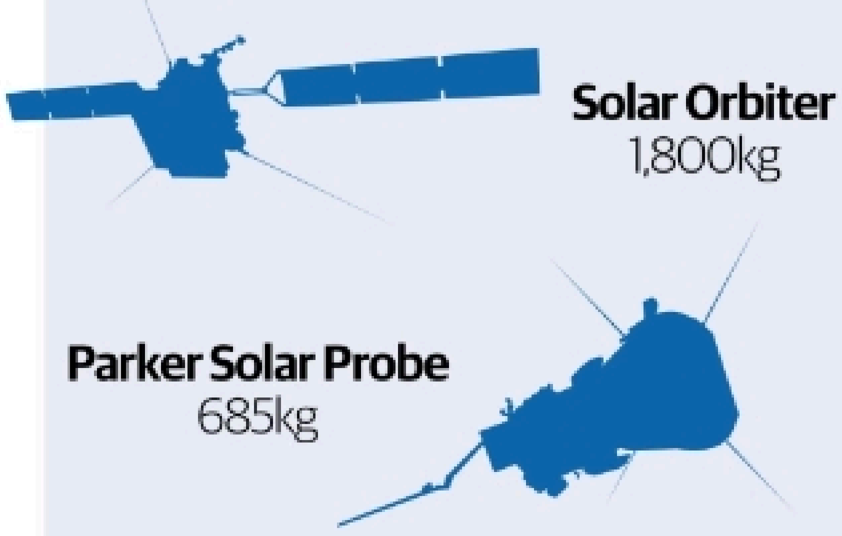
© NASA

Head-to-head

Solar Orbiter vs Parker Solar Probe

These two missions are following slightly different paths with slightly different mission objectives. The Parker Solar Probe was designed to withstand radiation 475 times the intensity than at Earth, as opposed to the Solar Orbiter withstanding 13 times the intensity.

In terms of dimensions, the Solar Orbiter is a much larger piece of equipment, with a height of three metres (9.8 feet). Once the solar panels are spread out, it reaches a wing span of 18 metres (60 feet). The largest part of the Parker Solar Probe in comparison is the hexagonal carbon-composite heat shield, which is 2.3 metres (7.5 feet) in diameter.



Vital statistics

99.9 Per cent = Percentage of the Solar System's matter in the Sun

4 million tonnes = Matter converted into energy by the Sun per second

6 Months = The time taken for SolO to orbit the Sun once

20 = Ultra-thin layers of titanium on heat shield's outer layer

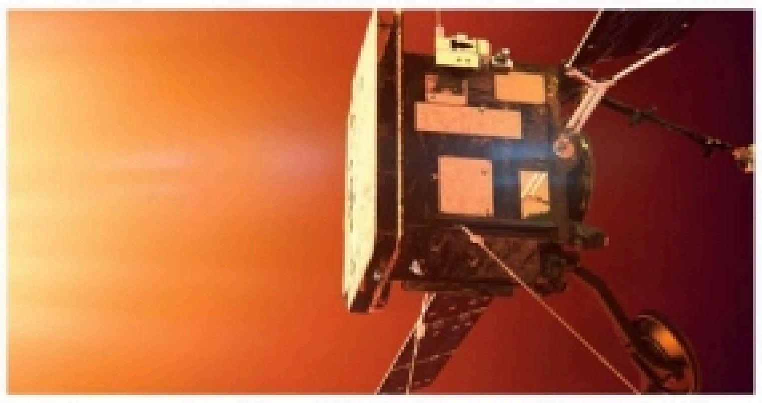
1.8 tonnes = The mass of the Solar Orbiter spacecraft

HOW TO...

Protect a spacecraft from the Sun

1 Knowing the enemy

The spacecraft will be in the midst of an extremely harmful environment. There will be unbearable temperatures and radiation peppering the spacecraft, so a set of precautions are needed in order to protect it.



© ESA

2 The first line of defence

The heat shield will guard against direct radiation, which will come in handy when the spacecraft is at its perihelion. This heat shield will be facing the Sun at all times during its orbit, so it will be constantly bombarded.

© ESA

3 Multi-layer insulation

As the name suggests, the spacecraft is coated in multiple layers of material that will allow the contents to be guarded against temperatures that reach as high at 500 degrees Celsius (932 degrees Fahrenheit).

© ESA

4 High-efficiency radiators

Some of the Sun's rays are inevitably going to be absorbed, and this could cause a problem if it heats up the spacecraft and its instruments. Waste heat will be rejected using high-efficiency radiators, which are directed towards cold space.

© ESA

THE VON BRAUN SPACE STATION

Bored of city breaks and cruises? 2025 could see the construction of the first hotel in low-Earth orbit

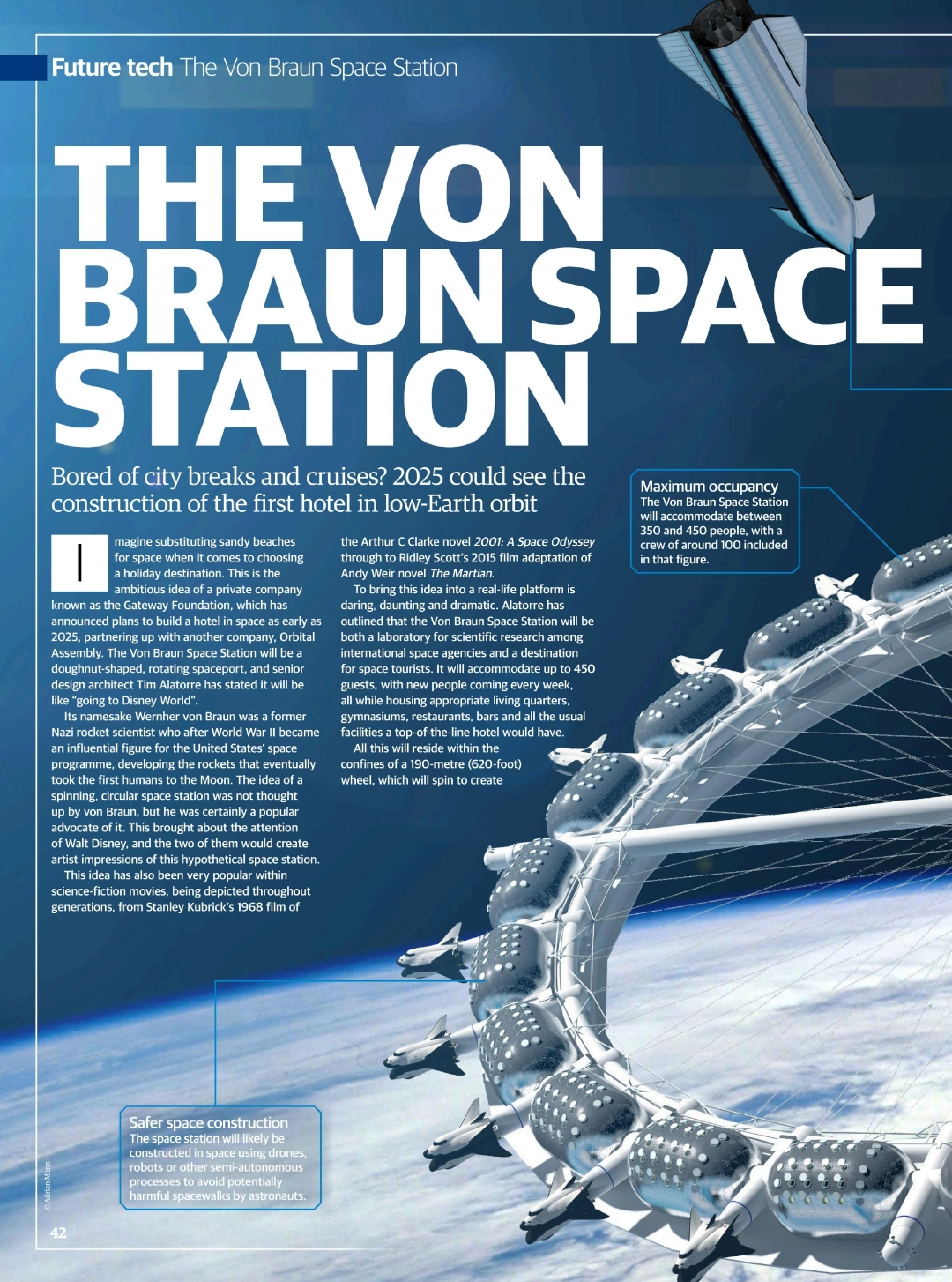
Imagine substituting sandy beaches for space when it comes to choosing a holiday destination. This is the ambitious idea of a private company known as the Gateway Foundation, which has announced plans to build a hotel in space as early as 2025, partnering up with another company, Orbital Assembly. The Von Braun Space Station will be a doughnut-shaped, rotating spaceport, and senior design architect Tim Alatorre has stated it will be like "going to Disney World".

Its namesake Wernher von Braun was a former Nazi rocket scientist who after World War II became an influential figure for the United States' space programme, developing the rockets that eventually took the first humans to the Moon. The idea of a spinning, circular space station was not thought up by von Braun, but he was certainly a popular advocate of it. This brought about the attention of Walt Disney, and the two of them would create artist impressions of this hypothetical space station.

This idea has also been very popular within science-fiction movies, being depicted throughout generations, from Stanley Kubrick's 1968 film of the Arthur C Clarke novel *2001: A Space Odyssey* through to Ridley Scott's 2015 film adaptation of Andy Weir novel *The Martian*.

To bring this idea into a real-life platform is daring, daunting and dramatic. Alatorre has outlined that the Von Braun Space Station will be both a laboratory for scientific research among international space agencies and a destination for space tourists. It will accommodate up to 450 guests, with new people coming every week, all while housing appropriate living quarters, gymnasiums, restaurants, bars and all the usual facilities a top-of-the-line hotel would have.

All this will reside within the confines of a 190-metre (620-foot) wheel, which will spin to create



Maximum occupancy
The Von Braun Space Station will accommodate between 350 and 450 people, with a crew of around 100 included in that figure.

Safer space construction
The space station will likely be constructed in space using drones, robots or other semi-autonomous processes to avoid potentially harmful spacewalks by astronauts.

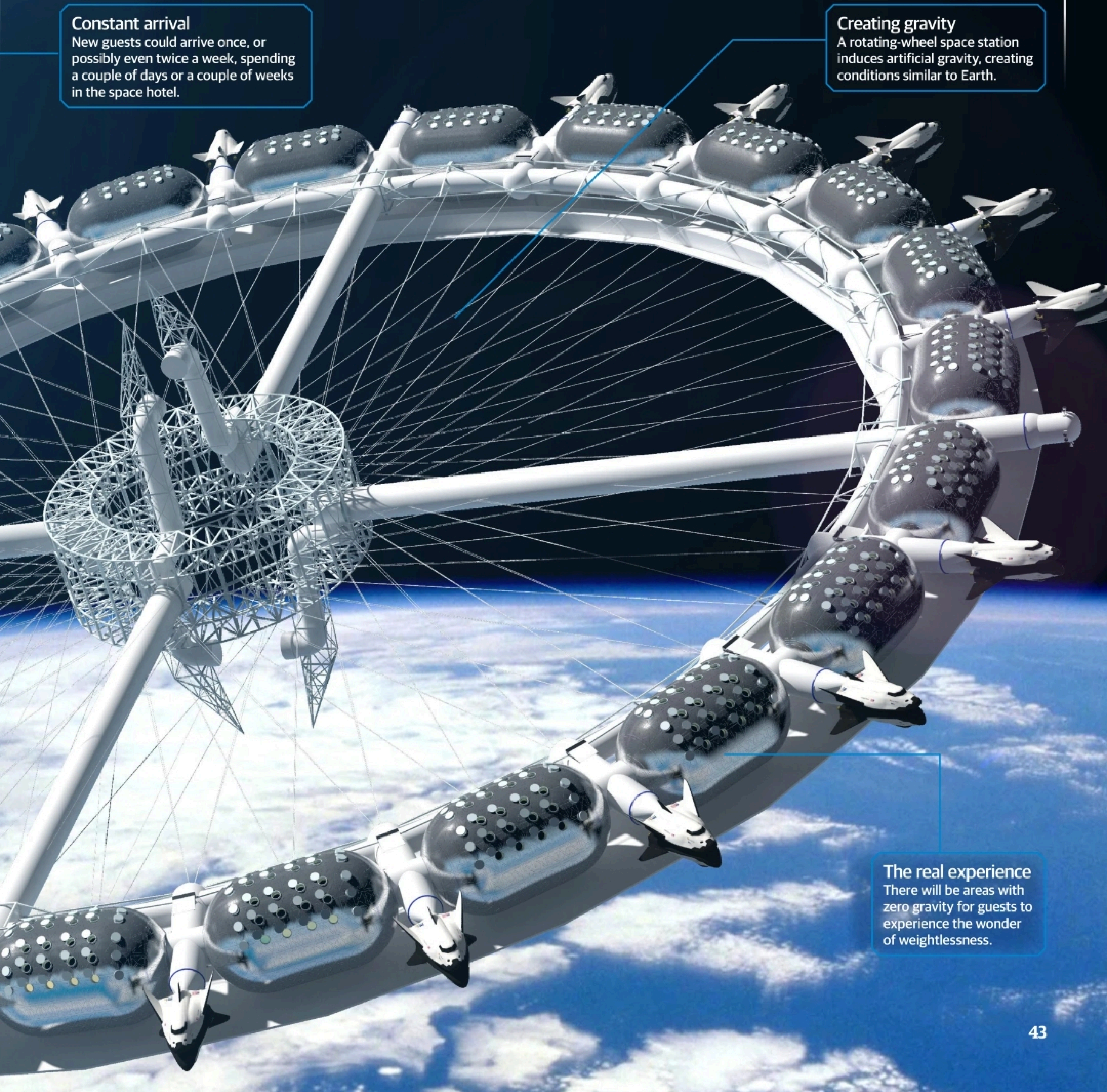
© Adrian Mann

artificial gravity. Instead of having to be strapped to a wall to sleep in zero gravity, which is what astronauts on board the International Space Station (ISS) do at the moment, you'll have a comfy bed to lay on. There also won't be any zero-gravity-related complications when using the toilet. Alatorre has said in previous interviews that he hopes the Von Braun Space Station will be operational in 2025, and completed in 2027.

Alatorre has stated that the Gateway Foundation feels it now has the potential to make this dream a reality due to the recent successes of other commercial aerospace companies, such as SpaceX. Low-cost launches make space construction financially feasible, and by using the same technologies developed for previous space stations, there isn't the need to create anything new.

However, there are still plenty of hurdles to overcome before such a project can begin construction. For starters, there are consistent and extreme temperature changes for stations in orbit as the constant, rapid revolutions around Earth lead to them lying either in the dark and cold of Earth's shadow or in direct sunlight. The station's designers will need to carefully plan the pressurised modules to handle the constant temperature changes to ensure the guests are comfortable.

The creation of this space station holiday destination would mean that guests going into space aren't astronauts who have spent years undergoing intense training to live in space. Astronauts have also shown that the body can undergo changes living in reduced gravity, meaning there are definitely some serious health precautions to the general public that need to be considered before such a getaway can be planned.



Constant arrival
New guests could arrive once, or possibly even twice a week, spending a couple of days or a couple of weeks in the space hotel.

Creating gravity
A rotating-wheel space station induces artificial gravity, creating conditions similar to Earth.

The real experience
There will be areas with zero gravity for guests to experience the wonder of weightlessness.

MYSTERIES OF THE UNIVERSE

WHAT'S WRONG WITH MARS' OXYGEN LEVELS?

© Alamy

The Curiosity rover has been amassing data that shows an unexpected change in the Red Planet's O_2

Reported by David Crookes

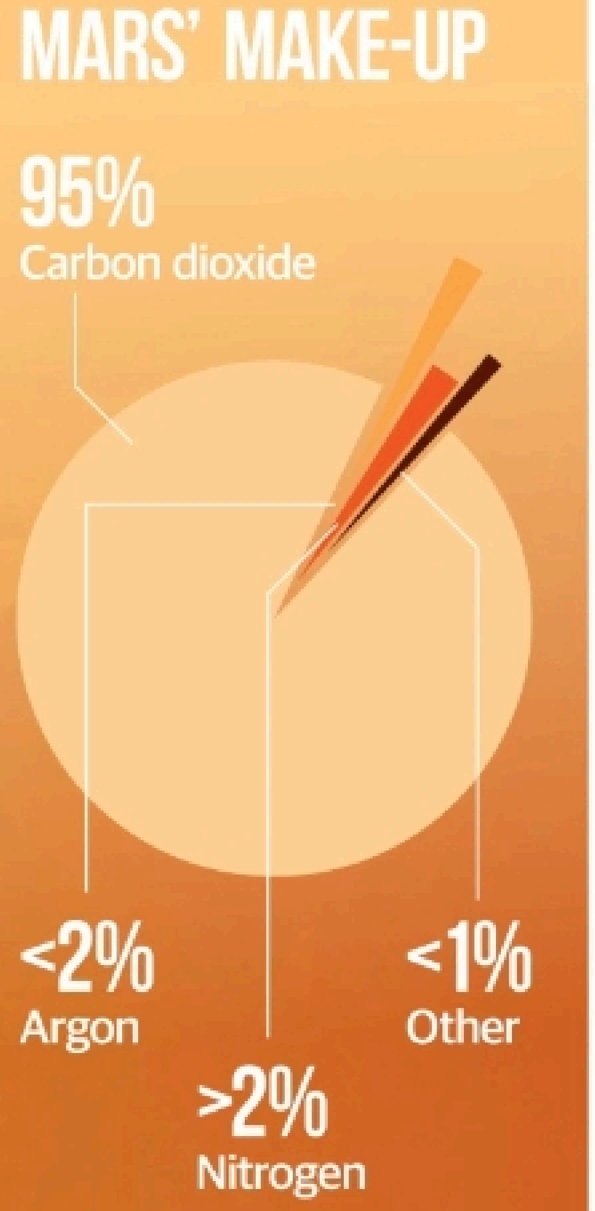
Curiosity has been trundling across the surface of Mars since 2012, revealing a lot of detail about the Martian climate and the Red Planet's geology. So far the rover has proven to be invaluable in showing that Mars could have once sustained life. It has uncovered evidence of ancient persistent water flows, discovered organic carbon in rocks and found two forms of radiation that could pose potential health risks to astronauts. But its work continues to astound and confound.

In November 2019, scientists revealed the results of a study of Curiosity's data that had been gathered directly above the surface of Gale crater, the rover's landing spot. Estimated to be as old as 3.8 billion years and 154 kilometres (96 miles) in diameter, its a significant area, but on this occasion the focus has been on the detected levels of oxygen – in particular its baffling, fluctuating behaviour.

To explain, over the course of some six years, scientists have worked out that the Martian air is mainly made up of carbon dioxide, which accounts for some 95 per cent by volume. The rest consists of molecular nitrogen (2.6 per cent), argon (1.9 per cent), molecular oxygen (0.16 per cent) and carbon monoxide (0.06 per cent), with the presence of nitrogen and argon proving constant and following a predictable seasonal pattern relative to the amount of carbon dioxide in the air.

The level of oxygen, however, is showing a very different and surprising pattern. According to a study headed by Melissa Trainer, a planetary scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland, oxygen levels have been seen to rise by as much as 30 per cent during the Martian spring and summer before dropping back in the autumn. What's more, when the scientists looked at the data over three Martian years, each of which lasts 687 days, they found that the pattern repeated itself each time. Scientists are now trying to discover why.

"The proportion of oxygen is found to rise in the summer by as much as a third above its predicted value of about 1,300 parts per million by volume," explains Sushil Atreya, a planetary scientist at the



THE THEORIES

Why is oxygen surging on the Red Planet during spring and summer?

Molecules are breaking apart in the atmosphere

One of the first considerations by scientists was the possibility that carbon dioxide (CO_2) or water (H_2O) molecules could be breaking apart in the atmosphere and releasing oxygen. This has now been ruled out because five-times more water would be needed, while CO_2 breaks up too slowly to account for the surge in levels.

Solar radiation is breaking up oxygen molecules

It's one thing to work on the issue of a surge in oxygen and another to account for why in autumn the levels fall back to what is predicted. It was thought that solar radiation could be breaking the oxygen molecules into two atoms and that these were subsequently being blown into space, but such a process would take many years.

Martian soil is holding the secret

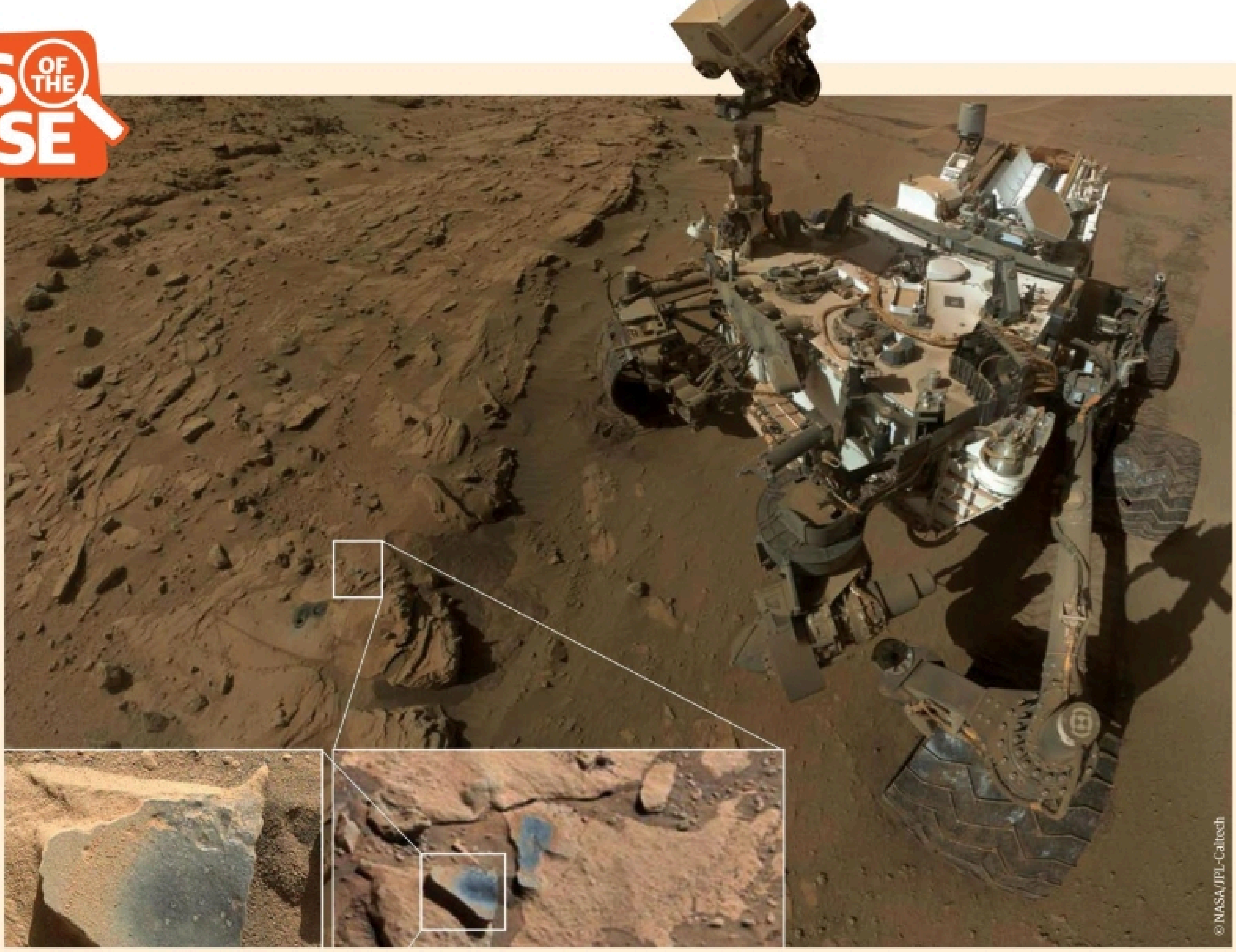
The most likely explanation is that hydrogen peroxide or perchlorates within the dirt of Mars are behind the surge. Both are a source of oxygen, and it is possible that heat and humidity could draw it out during the spring and summer. This would need to happen on a large scale, but it is certainly a strong possibility.

The oxygen is being produced by aliens

Oxygen is associated with life, and it can be produced by living organisms such as microbes. Therefore there is a chance that oxygen is not being produced from the air or rocks and that a biological chemical reaction is taking place instead. It would be the most exciting explanation, but it's one being ruled out – for now at least.

MARS BY THE NUMBERS

6,794	Diameter in kilometres – around half that of Earth
687	Number of Earth days in a Martian year
0.375	The strength of gravity when compared to the Earth standard
2	Number of Martian moons
-62.8°	Average temperature on Mars
6	Number of Mars-sized planets it would take to fill Earth's volume
45	Missions launched to Mars since 1960
19	Number of successful missions in that time
25	The height of the tallest Martian mountain, Olympus Mons, in kilometres



© NASA/JPL-Caltech

Above: When Curiosity found rocks containing manganese-oxide materials on Mars in 2016, it suggested a once-higher abundance of free oxygen on the Red Planet

University of Michigan and part of the scientific team. "On the other hand, nitrogen and argon – both of which also have a long lifetime on Mars – behave normally." Indeed, the top reported rise of oxygen was equivalent to an extra 400 parts per million, and this was detected by the quadrupole mass spectrometer instrument on board the Sample Analysis at Mars (SAM) – a portable chemistry lab inside Curiosity.

"The presence of oxygen in the atmosphere of Mars can be attributed to the chemistry between the main gas of the atmosphere, carbon dioxide, and a smaller component, water vapour, together with energy from the Sun," says Atreya.

"Numerical models of the past several decades had predicted that oxygen levels in the atmosphere of Mars should remain constant throughout the year because the lifetime of the gas against all known loss processes is fairly long, far exceeding the length of a year on Mars. It was a bit jarring to discover that wasn't the case."

There is a possibility that microbial life is behind this surge, since oxygen can be produced biologically. If this was the case then the explanation would be incredibly exciting, but scientists are leaning more towards an abiotic source, which means the surge is likely down to chemistry that is related to water and rocks.

Unfortunately there is no known chemical process that easily accounts for the observations. Scientists know that the 0.16 per cent of oxygen in the atmosphere is due to ultraviolet light reacting with carbon dioxide and water vapour to break those molecules into their components. Chemical reactions then cause the oxygen to form carbon dioxide, creating a cycle. But if this was to account for the rise which scientists have observed from Curiosity's data, then the process would need to be far more rapid.

Likewise, there would need to be five-times as much water above Mars to account for the increased levels of oxygen. As such, scientists believe a more likely source of the oxygen is hydrogen peroxide or perchlorates which exist on a widespread level in the Martian soil. If it's the former, it would point to deep, underground sources of oxygen of a sufficient amount to account for a spike, and yet the evidence is that there is not such an abundance.

As for the perchlorates, NASA's Viking 1 and 2 spacecraft detected these toxic, stable salts composed of chlorine and oxygen when landing on Mars in 1976, and an experiment showed that heat and humidity could release oxygen. Yet the conditions under which that research was carried out were not the same as Mars in the spring, and so no firm conclusions can be made.

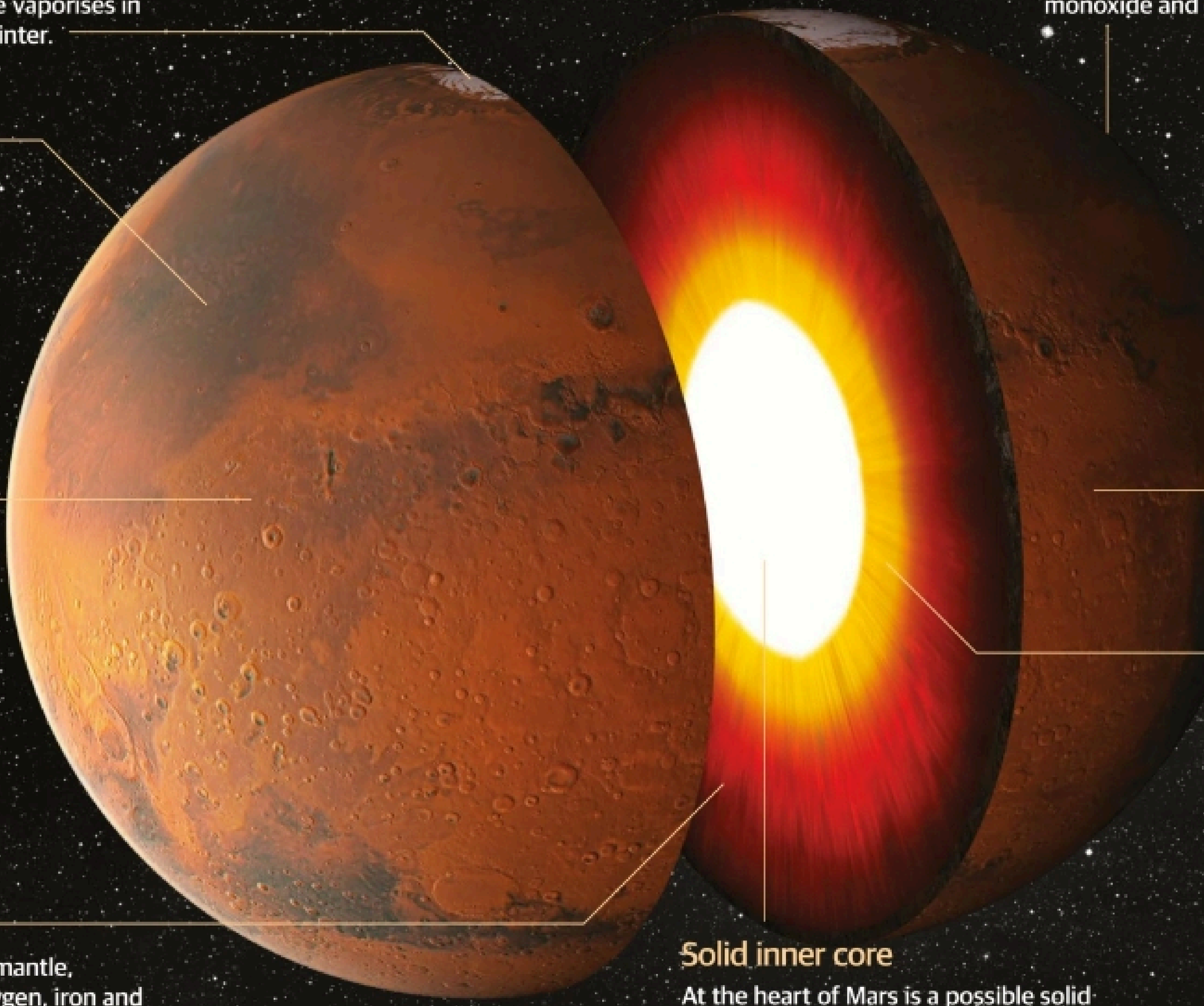
Even so, in 2009 the Phoenix lander discovered that perchlorates made up between 0.4 and 0.6 per cent of a collected soil sample, so there is a good chance that oxygen could be released under a set of conditions, perhaps when cosmic radiation breaks them down. Quite why the oxygen levels drop in autumn is just as mystifying, though – something seems to be removing it from the air. The gas is also soaring and plunging randomly. If cosmic radiation really was to account for the spike each year, then it would have to be happening at a faster rate than scientists believe it to be.

"The observed oxygen rise requires a source in the surface," Atreya tell us. "The atmosphere does not produce the increase. At least three potential

> "Oxygen is found to rise in the summer by as much as a third above its predicted value" **Sushil Atreya**

INSIDE THE RED PLANET

How is Mars' composition contributing to the atmosphere?



Ice caps

Mars has two permanent polar ice caps that are a mixture of water ice and carbon dioxide ice – carbon dioxide being one carbon and two oxygen atoms. Carbon dioxide ice vaporises in summer and freezes in winter.

Deep in the dirt

Hydrogen peroxide – which can decompose into water and oxygen gas – is found in the Martian soil alongside perchlorates, which also contain oxygen.

Rusty surface

Since the Martian soil contains iron oxide, a product of the reaction between iron and oxygen, it lends a rusty colour to the surface of the planet. The dust is blown into the atmosphere, colouring the sky too.

Surround mantle

Beneath the crust is the mantle, comprising of silicon, oxygen, iron and magnesium. Scientists have concluded that the upper mantle is more oxidised than the deep interior.

Solid inner core

At the heart of Mars is a possible solid inner core made of iron, nickel, sulphur and perhaps even oxygen. Since the core is static, there is no planet-wide magnetic field.

Thin atmosphere

Mars' atmosphere is 100-times less dense than our own planet's and is 95 per cent carbon dioxide and 2.7 per cent nitrogen. There are tiny traces of argon, carbon monoxide and oxygen.

Methane and oxygen

Curiosity has found traces of methane, which surges in the summer, as well as rising oxygen levels in the spring and summer. Methane appears to be released from distinct Martian regions.

Liquid iron-sulphur core

Mars appears to have a molten silicate outer core. A gravity map released by NASA in 2016 provided strong evidence of this by allowing scientists to analyse tides present in the mantle and outer crust of the planet.

non-biological reservoirs exist in the surface: perchlorates, hydrogen peroxide and the rocks oxidised by water or brine in the past when Mars was presumably wetter and warmer, or even today. It appears pretty challenging to dislodge large amounts of oxygen from rocks, however.

"On the other hand, the other two sources look promising for the excess oxygen. The devil is going to be in the details, as it's not just the increase in oxygen in summer, but also its decline in late summer and autumn back down to the levels predicted by atmospheric chemistry models which must be understood." But that's not the end of it. As if the situation wasn't mysterious enough, the extent of the rise has been shown to vary year after year. "The amount of the summertime increase in oxygen varies somewhat from one Mars year to the next," says Atreya. "Is that surprising? What's surprising is that oxygen increased at all. The year-to-year fluctuations seem to reflect fluctuations in the mechanism behind the increase."

And yet oxygen is not alone in showing such seasonal fluctuation. Methane inside Gale crater also rises in the summer and falls in the autumn, and it does so by as much as 60 per cent. This was

ATMOSPHERIC CONSTITUENTS

How Mars' gasses are fluctuating through its four seasons

When carbon dioxide – the most abundant gas in the Martian atmosphere – freezes over the poles of Mars, pressure drops across the hemisphere. Pressure rises again when the polar caps melt and CO_2 is released. In both cases, gases are redistributed so that they are equalised from hemisphere to hemisphere. Scientists should, therefore, be able to predict the proportion of molecular nitrogen, argon, molecular oxygen and carbon monoxide in proportion to carbon dioxide.

Carbon dioxide – annual average 95 per cent by volume: The barometric pressure on Mars cycles as carbon dioxide freezes and is re-released from the polar ice caps.

Molecular nitrogen – annual average 2.6 per cent by volume: Behaves as expected, following the pressure changes caused by carbon dioxide fluctuations, with a delay and a seasonal variation of ten per cent.

Argon – annual average 1.9 per cent by volume: Behaves as expected, again following the pressure changes, with a delay and a seasonal variation of ten per cent.

Molecular oxygen – annual average 0.16 per cent by volume: Significant seasonal variability that changes year to year. There can be a spring and summer spike of as much as 30 per cent.

Carbon monoxide – annual average 0.06 per cent by volume: Tracks the season trend in argon, but some divergence from the seasonal trend merits further investigation.

Methane – annual average 0.00000004 per cent by volume: Undergoes a seasonable variation by a factor of -3 from 0.24 to 0.65 parts per billion by volume.

discovered by SAM's tunable laser spectrometer, which has done a fine job in picking methane up, given that the quantity is a tiny 0.00000004 per cent on average. Scientists wonder if there is some sort of correlation between the behaviour of oxygen and methane, with the general hunch being that it will indeed be the case.

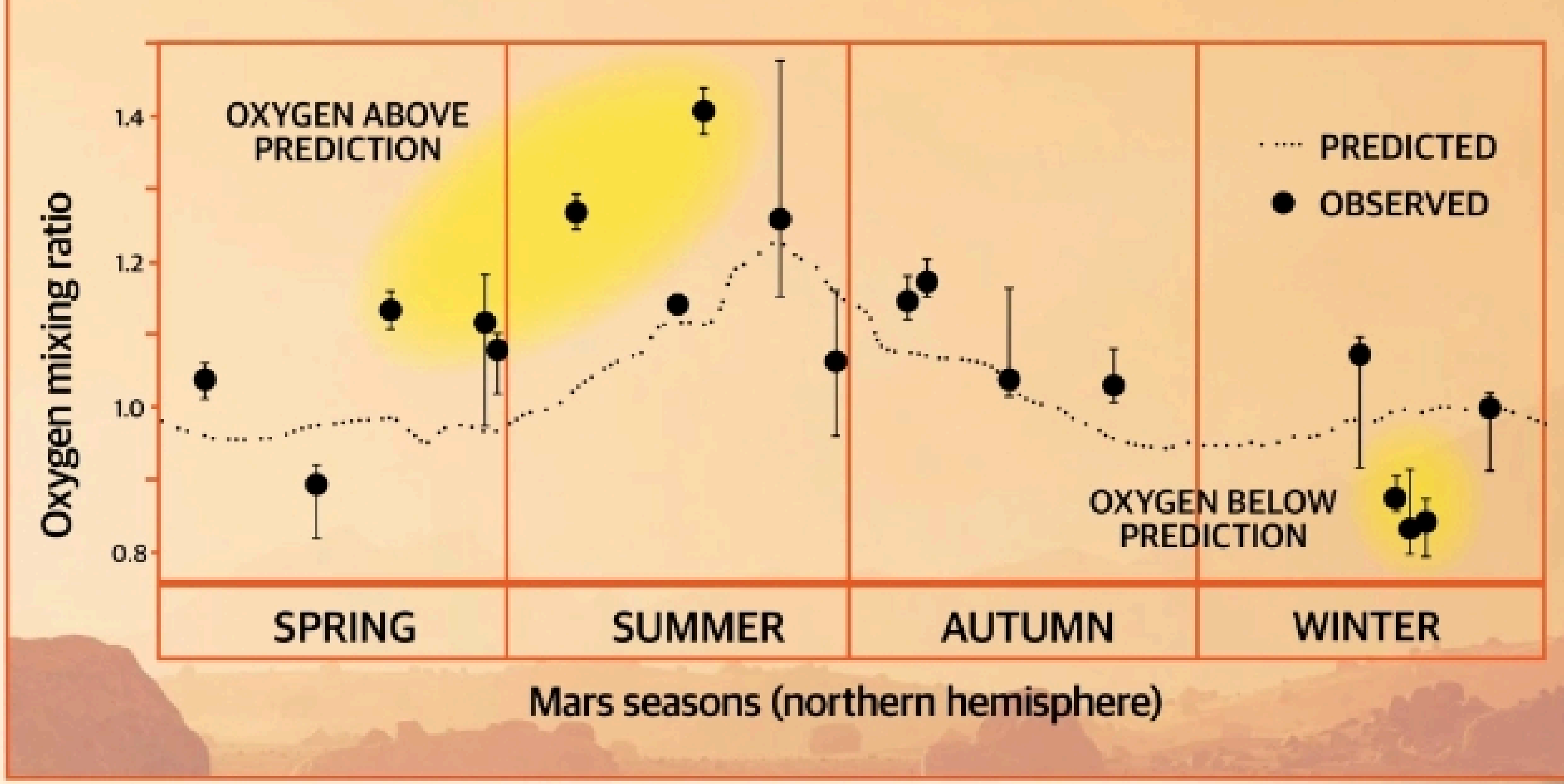
"Both gases increase in summer, which makes me think the same mechanism that triggers the release of oxygen also causes methane to be released to the atmosphere from its subsurface reservoir, discounting the occasional spikes seen in methane," says Atreya. "Oxygen and methane show a similar trend over part of the year, but some gaps remain in the data."

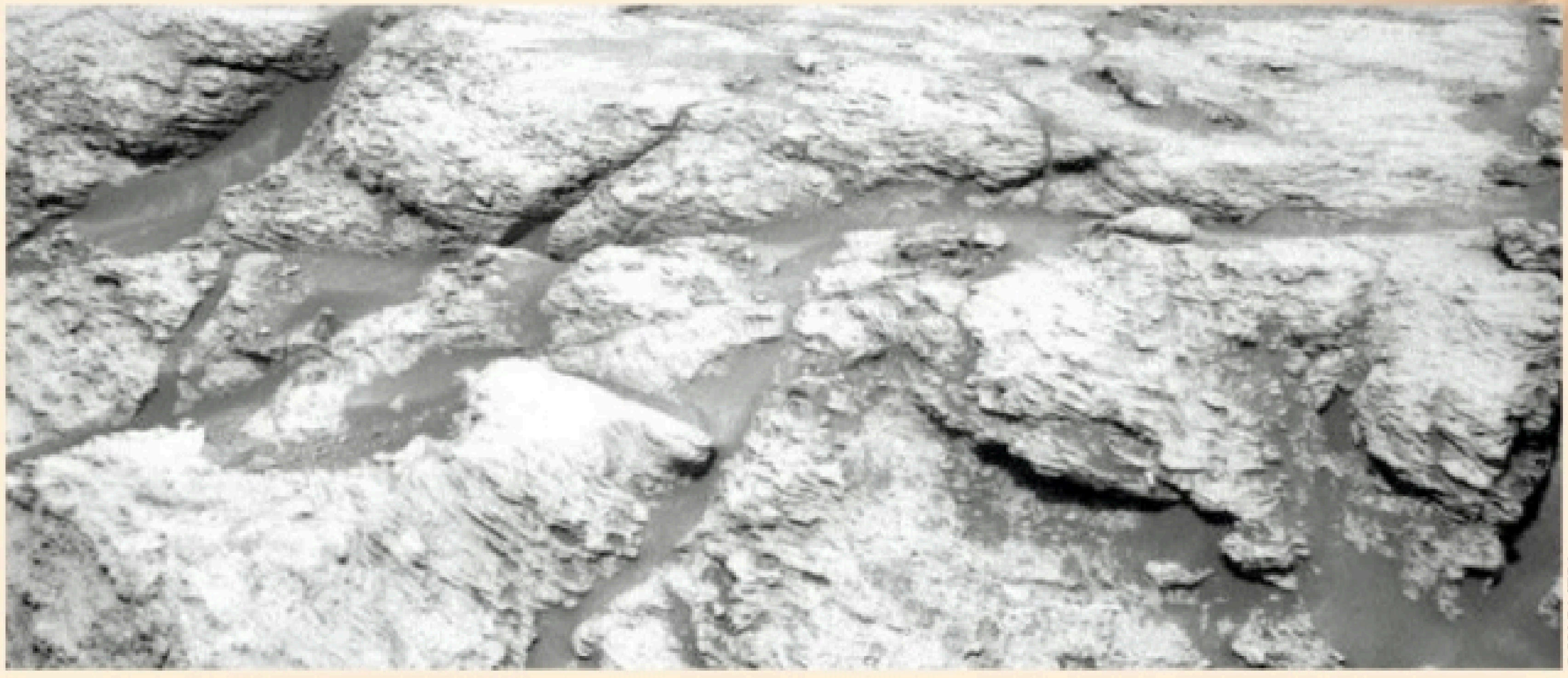
As such, it's not proving to be a straightforward case to solve, but some potential problems can at least be ironed out. Tests on Curiosity's instruments have shown that they are not malfunctioning. "Multiple tests of the instrument and testbed experiments in the lab showed that SAM is working properly," says Atreya. But, in terms of methane at least, only the rover is detecting methane. Go higher in the atmosphere, well away from the ground, and methane is not being picked up.

Indeed, the European Space Agency's Mars Express passed over Gale crater five hours after Curiosity observed a surge in methane of 21 parts per billion by volume and found none. And even Curiosity has found moments when the level is less than one part per billion, making the amount of methane practically bereft.

Given that the ExoMars Trace Gas Orbiter has also struggled to measure methane and yet Curiosity points to it being persistently present, it's going to take a while yet to figure this one out, let alone work out whether or not there is a connection.

GALE CRATER SEASONAL VARIATIONS

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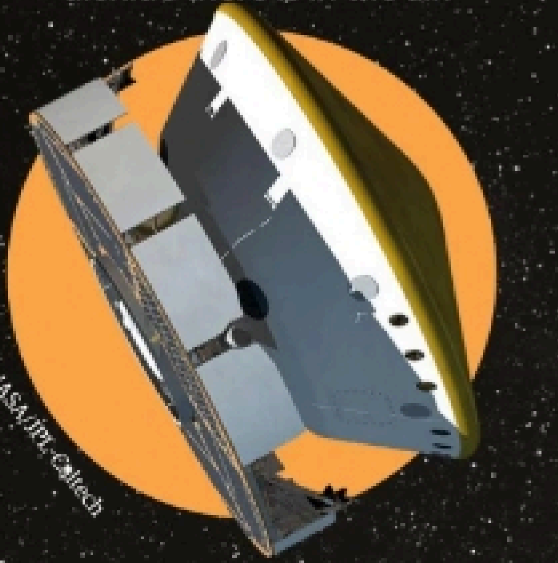
MISSION PROFILE

Meet the spacecraft keeping an eye on Mars

Mars Science Laboratory

Curiosity measured the gases in Mars' atmosphere using the quadrupole mass spectrometer instrument in the Sample Analysis at Mars portable chemistry lab, with the data showing the amount of oxygen rises in spring and summer, although not relative to how much carbon dioxide there is in the air.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Viking landers

Two Viking landers carried out biological experiments in 1976 in a bid to find biosignatures that could point to microbial life. They were able to measure the gases in Mars' atmosphere, but only over the course of a few Martian days, which was nowhere near enough to study seasonal fluctuations.

Source: Wiki © Don Davis

Mars Scout Program

In 2008, Phoenix landed on Mars to assess habitability and the history of water on the planet. It found that the Martian soil contains perchlorates, which are charged particles that consist of an atom of chlorine surrounded by four oxygen atoms. As an oxidant, perchlorates can release oxygen.

© Adrian Mann

ExoMars Trace Gas Orbiter

Put together by the ESA and Roscosmos, this mission has sought a better understanding of methane and other atmospheric gases that are present around Mars. Its orbiters did not see the methane burst detected by Curiosity, however, even though it was recorded at its highest level yet back in June 2019.

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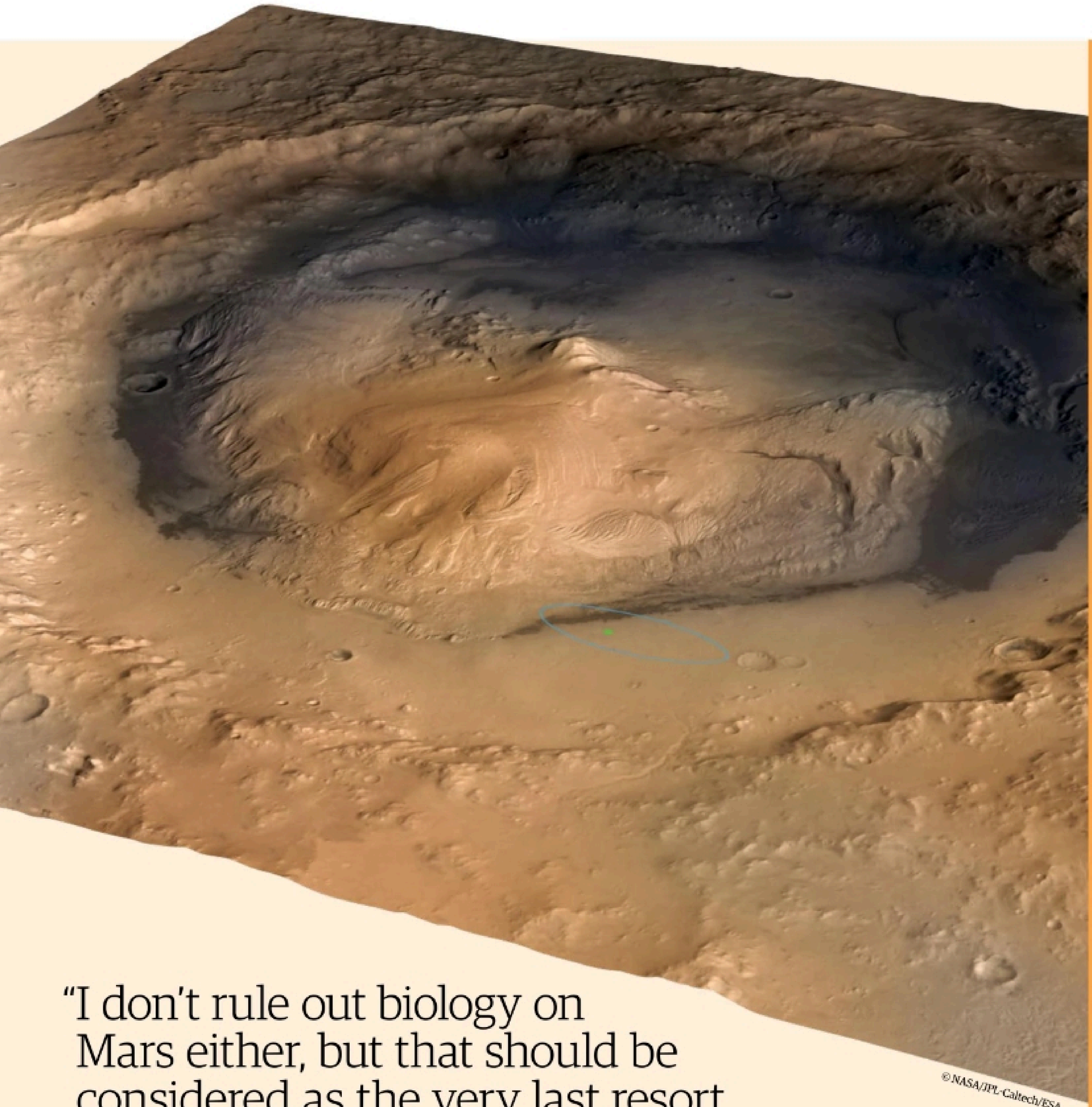

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> "I don't rule out biology on Mars either, but that should be considered as the very last resort, only if all else fails" **Sushil Atreya**

Going back to the oxygen, however, there is a suggestion that there is a source in the near-surface that interchanges with the atmosphere.

Does it rule out life? "Either biology or geology can generate oxygen and methane," says Atreya. "On Earth, biology is by far the dominant process, and I don't rule out biology on Mars either, but that should be considered as the very last resort, only if all else fails. It's absolutely essential to rule out the abiotic processes first."

To do that, it's clear that more studies will need to be made, and there will be missions in the future that should help scientists make headway. "Continued measurements with SAM at the surface of Mars will also fill in some gaps in the data, while laboratory studies and electrochemical modelling would be important in untangling the exciting new results," Atreya says. "Work is ongoing in all areas, and future missions should pay close attention to processes that might be happening beneath the surface of Mars."

For a better set of results, oxygen and methane readings could be taken more regularly. The scientists were working on the basis of 19 data points over the equivalent of six Earth years, which makes it hard to see what is happening day by day.

"As with any new finding, especially an unexpected one, you want to repeat the measurement to be certain," says Atreya. "Except that on Mars, one has to wait two years for the same season to roll around again."

Even so, no one can say for certain whether the phenomena being seen at Gate crater will apply across the whole of the Red Planet. It could only apply to specific areas, and that's something the ExoMars Trace Gas Orbiter hints at, given it can't detect methane.

Atreya is wary of jumping to conclusions, though, and he says this current study should be a warning for those searching for alien life. "The recent Mars findings further reinforce the importance of continued exploration of the Solar System using state-of-the-art technology," he says. "They are also a reminder to avoid the temptation of declaring the presence of life if and when oxygen and methane are detected together on an Earth-sized extrasolar planet with surface liquid water in the habitable zone of star. Be ultra-cautious!"

Left: When this image was taken by Curiosity in June 2019, the largest amount of methane gas had been detected

Above: The data which shows a surge in oxygen during spring and summer was taken from within the Gale crater

Right: Mars has a lot of as yet unexplained activities

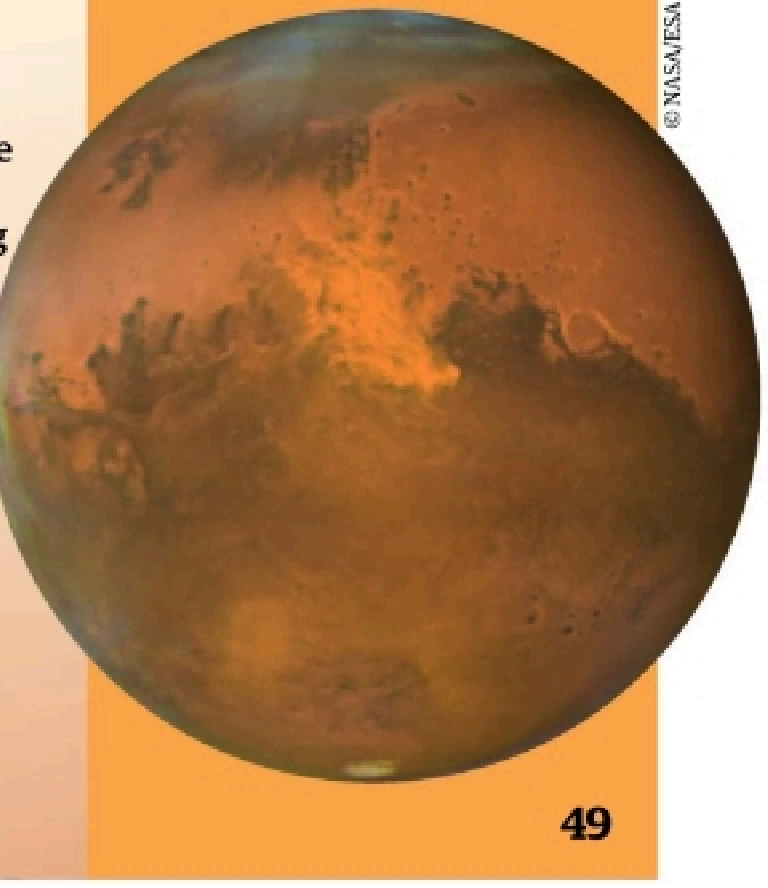
QUICKFIRE QUESTIONS

Do any of the environmental factors explain the seasonal behaviour?
No. None of the environmental factors, including surface and air temperatures, water vapour and humidity and dust or UV at and above the surface can explain the observed seasonal behaviour in oxygen.

How does Mars' atmosphere compare to Earth's?
Here on Earth, we have a dense atmosphere made up of five layers: the troposphere, the stratosphere, the mesosphere, the thermosphere and the exosphere. Mars' atmosphere is one per cent of ours and so it's very thin.

Has Mars' atmosphere always been thinner than Earth's?
Studies suggest that Mars once had an atmosphere as thick as Earth's, but that gases have been lost to space over time, with ions getting picked up by the solar wind. Mars used to be warm and wet rather than incredibly dry and cold as it is today.

Can humans benefit from Mars' atmosphere?
Yes. There has been a lot of thought given to using carbon dioxide, which is in great abundance within the atmosphere, for the creation of rocket fuel that would power humans back from any future manned missions.



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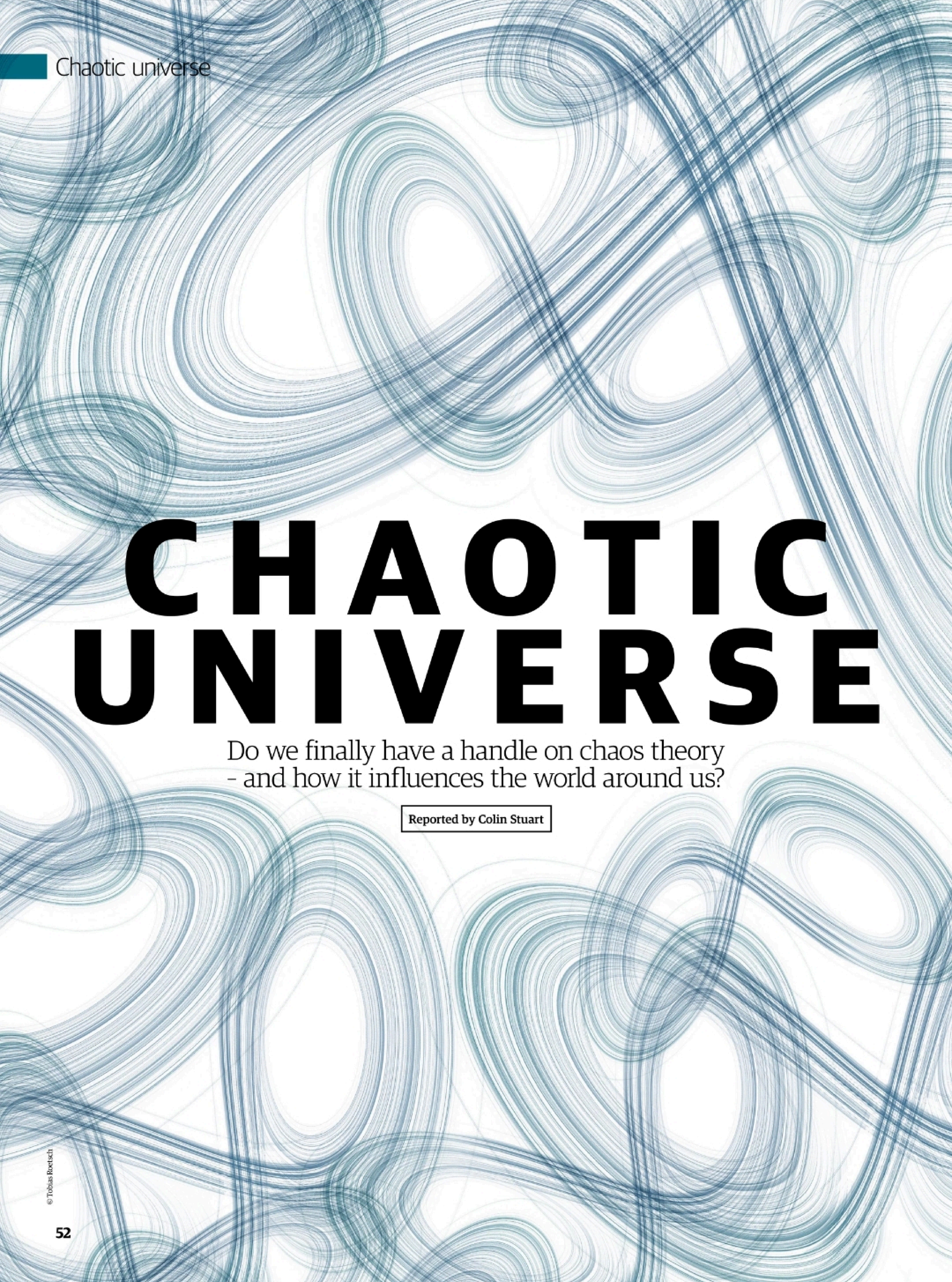

CHAOTIC UNIVERSE

Do we finally have a handle on chaos theory - and how it influences the world around us?

Reported by Colin Stuart

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When it comes to surviving in space, the tiniest things can be the difference between life and death. As Canadian astronaut Chris Hadfield said: "An astronaut who doesn't sweat the small stuff is a dead astronaut." That may be the case for human space travel, but astronomers are increasingly suspecting the same mantra also applies to the wider universe. When it comes to the cosmos, it seems chaos theory is king.

Chaos theory traces its origins way back to the 19th century. French polymath Henri Poincaré was attempting to win a prize of 2,500 crowns – a third of a professor's yearly salary – offered up by King Oscar II of Sweden and Norway to celebrate his 60th birthday. To win you had to predict the orbits of the planets. Isaac Newton's work on gravity allows you to foretell the future positions of two gravitationally intertwined objects with clockwork precision. Yet throw a third object into the mix and that ability vanishes. Poincaré failed to solve this 'three-body problem', but was awarded the prize nonetheless for important insights into why it is such a thorny conundrum to crack.

Russian mathematician Sofya Kovalevskaya also carried out important work on the problem. The puzzle is difficult because even the smallest changes in a system with many moving parts can lead to huge differences later down the line. That, in a nutshell, is the essence of chaos theory. "We wouldn't have chaos theory if we didn't study planetary orbits," says Dr Paul Sutter of the Flatiron Institute in New York.

American mathematician and meteorologist Edward Lorenz compared it to the flap of a seagull's wing affecting the weather. He later switched his metaphorical creature to a butterfly, and to this day it is still known as the 'butterfly effect'. In the 1960s Lorentz was using computers to try and predict weather patterns on Earth, but he found that the outcome was wildly different even though it looked as if he was modelling the same situation each time. Further investigation revealed that tiny rounding errors in the values fed into the computer blew up into major differences in the predicted forecast.

Today Lorenz gets the lion's share of the credit, but Mary Cartwright and John Littlewood analysed chaotic patterns in radio signals during World War Two. To this day chaos theory places a limit on how far into the future we can accurately predict the weather. Chaos theory makes meteorology an imperfect science.

Mathematicians have been studying chaos theory ever since Lorenz's insights. Somewhat counter-intuitively, they have found that chaotic systems are not as unpredictable as they first seem. "It helps us to identify patterns, key elements, hidden rhythms and orders in systems that are not normally apparent," says Sutter. Period doubling is just one example. In a chaotic system, the time it takes for a pattern of behaviour to repeat increasingly grows to twice as long as before. Eventually the behaviour takes so long to replicate itself that the system appears lacking in an underlying order – it looks chaotic. However, there is method in the madness if you know where to look. In 1975 American mathematician Mitchell Feigenbaum, one of the pioneers of chaos theory, discovered that the ratio of the points at which the period doubles increasingly approach the number 4.6692… as the system becomes more chaotic. This number is now known as the Feigenbaum constant in his honour.

Applying chaos theory to the cosmos could help us to explain how the Earth came to be the life-hosting planet it is today. The Sun was one of many stars formed when a vast cloud of interstellar gas and dust collapsed around 5 billion years ago. "Tiny little changes in that gas cloud can lead to very big changes in the population of stars that form," says Sutter. An extra little clump of dust here, a tiny bit of extra spin there and the Sun could have been a very different star, or even not have formed at all. Star formation may look like a chaotic system, but there could be an underlying mathematical order that reveals the likelihood of forming the kind of stars suitable for sustaining habitable planets. In turn that could point us to the appropriate corners of the nearby universe to search for alien life. The creation of new stars is often studied by creating very complex computer simulations. "Chaos theory gives us a mathematical tool to help us get a handle on what's going on," says Sutter.

Why is our Solar System a good place for life to emerge, evolve and thrive? Our cosmic backyard looks serene today, with planets neatly drifting around the Sun in well-behaved orbits and relatively few unstable asteroids left to careen into them. Yet today's peace and quiet belies a tumultuous youth. "We suspect that a lot more planets formed around the Sun and some of them were on chaotic orbits," says Sutter. Tiny changes in their speed

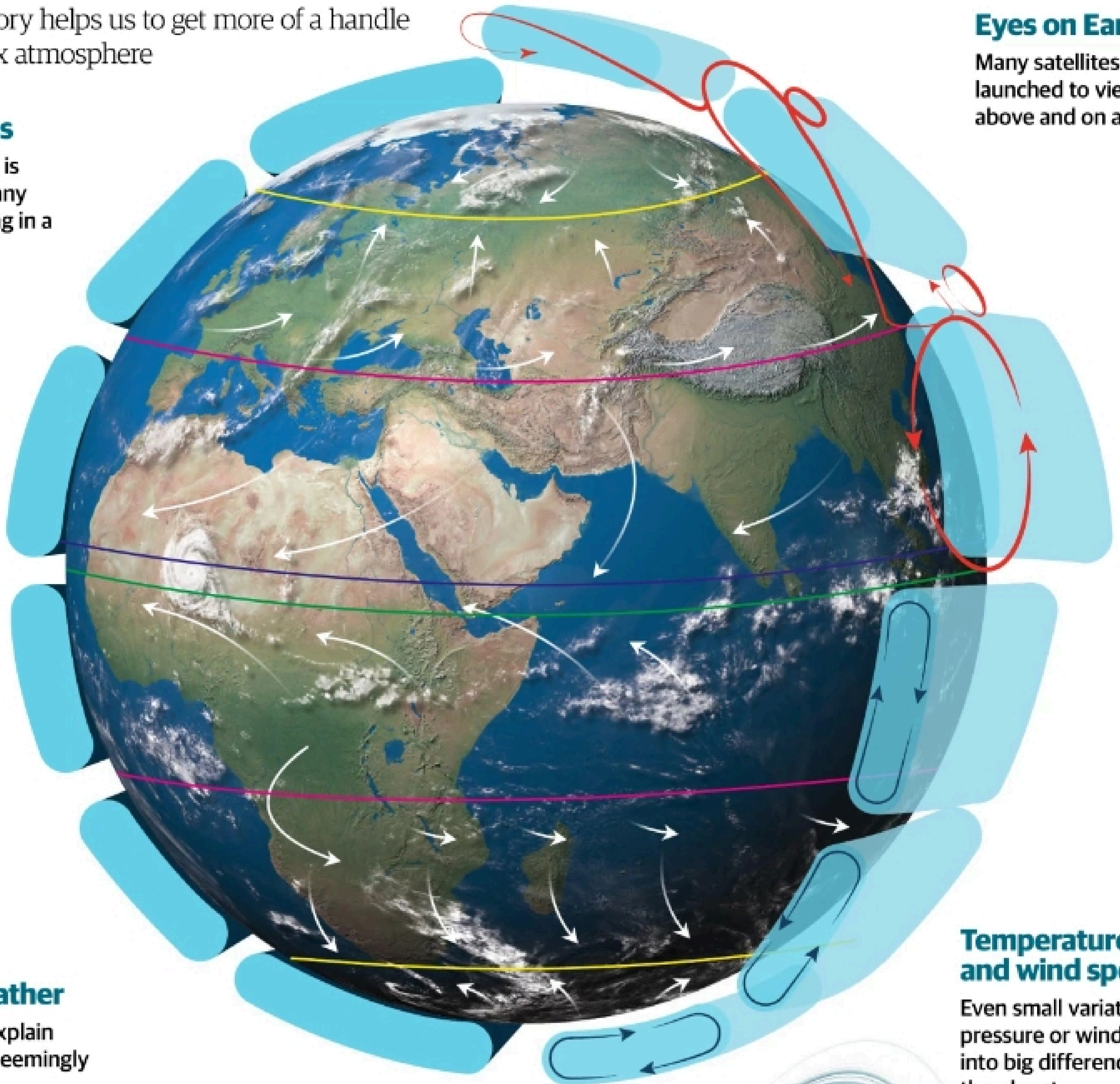
© Hulton Deutsch/Getty

Above: French mathematician Henri Poincaré was one of the first to grapple with chaos theory

> "It helps us to identify patterns, key elements, hidden rhythms and orders in systems" **Paul Sutter**

Applying chaos to the weather

The mind-bending theory helps us to get more of a handle on our planet's complex atmosphere



Our complex systems

The Earth's weather system is incredibly complex, with many different particles interacting in a variety of ways.

Eyes on Earth

Many satellites in orbit have been launched to view our weather from above and on a grander scale.

Jet streams

These fast-moving channels of air affect the weather in different parts of the world depending on their speed, latitude and movement.

Chaos solves the weather

Chaos theory attempts to explain underlying patterns in this seemingly random maelstrom of data.

Temperature, pressure and wind speed

Even small variations in temperature, pressure or wind speed can build up into big differences elsewhere on the planet.

Chaos theory in real life

It thrives across the universe – and also crops up in some everyday examples

Heart vs head

Parts of the human body may exhibit chaotic patterns. There's some evidence that arrhythmia – when your heart beats out of rhythm – may occur in a chaotic way. It's possible that our brain activity has chaotic tendencies, with some suggesting that electroencephalograms show it in action.

The natural world

Chaos is rife in the animal kingdom. Biologists studying the Canadian lynx have found that their population grows in a chaotic way. Small changes in food supplies, mating habits or the spread of diseases can become magnified into big differences in animal numbers.

Bless your cotton socks

In 1963, Polish mathematician Benoit Mandelbrot found recurring patterns in data on cotton prices from 1900 onwards that suggest they vary in line with chaos theory. They didn't follow the famous 'bell curve' as a lot of data sets tend to.

In a jam

Often traffic jams can seem to clear suddenly and without any obvious cause. Tiny changes to the flow of cars can build into sizeable log-jams that vanish almost as soon as they arrive.

Make codes harder to crack

Cryptographers – those responsible for setting and deciphering codes – are big users of chaos theory. A message is scrambled and unlocked using a series of keys, and some computer-based encryption methods – including online image encryption – utilise chaos maps to construct those keys.

Up to the job?

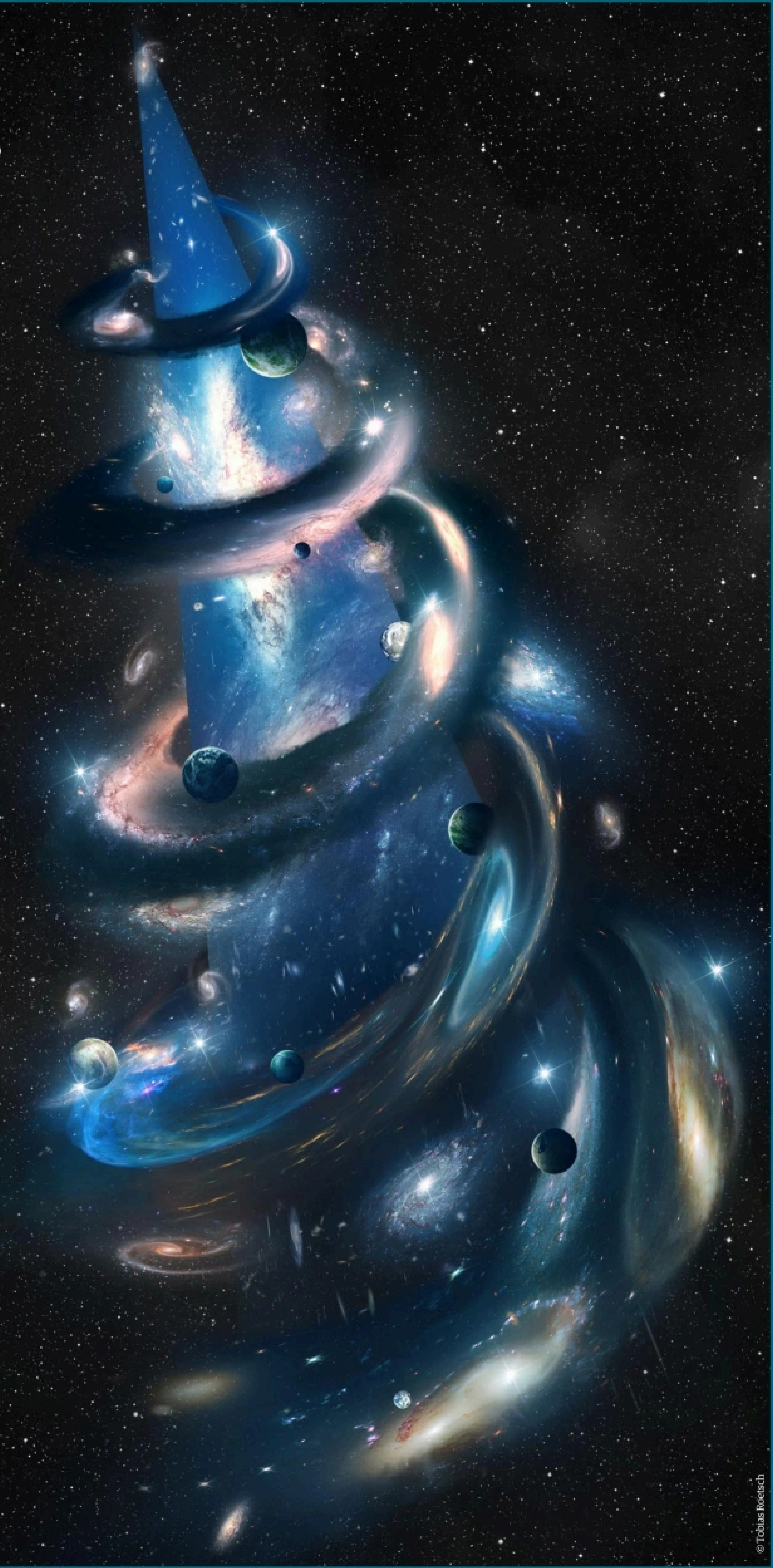
Even the labour market hasn't escaped the scrutiny of chaos theorists. The way we work, apply for jobs and move between companies could well follow chaotic patterns. Insights could lead to better decisions and a more streamlined workforce in the future.

Taking stock

The ups and downs of the stock market are notoriously hard to predict. That's why the adage to success is "time in the market rather than timing the market". It may be possible that chaos theory could reveal hidden patterns in the lightning-fast trades on the world's exchanges.

Better understanding babies

The chaos in our lives starts early. Researchers have shown that they can better understand the warning signs of a condition called fetal hypoxia – where a developing fetus is starved of oxygen – if they model the situation using chaos theory.



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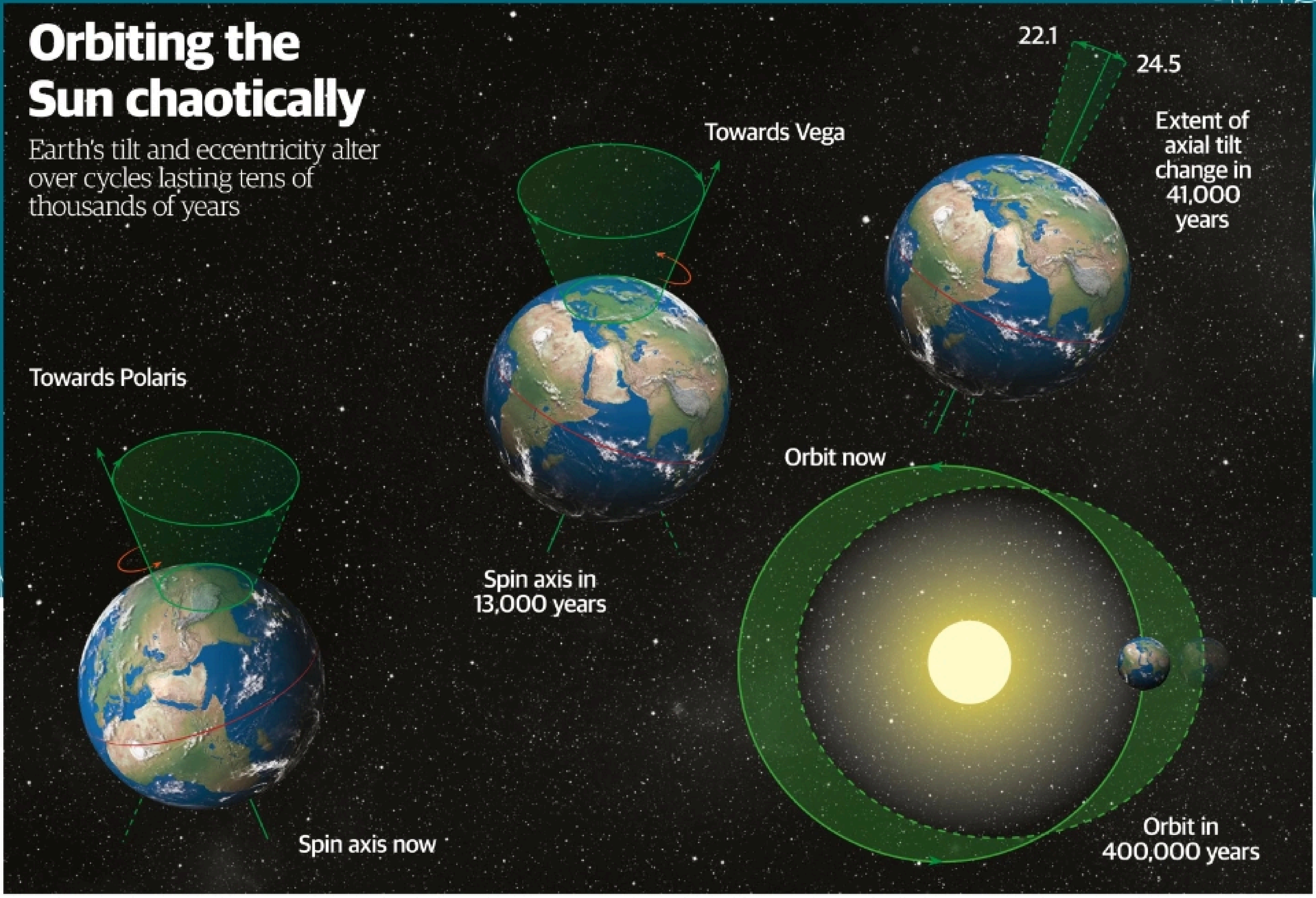
Orbiting the Sun chaotically

Earth's tilt and eccentricity alter over cycles lasting tens of thousands of years



and positions would have been amplified into considerable effects. Eventually they either crashed into other planets – just such an event is thought to have formed the Moon – or were jacked up onto such steep orbits that they were ejected from the Solar System entirely. "Only the ones born in good places at good times get to stick around," Sutter summarises. Working out what constitutes a good place or good time is key in hunting out habitable worlds in other solar systems. Astronomers have spotted a whole host of weird-looking solar systems, including a planet that orbits its star in the opposite direction to its neighbours, probably because its orbit became so inclined that it flipped right over the poles of the star. This work is a shot in the arm for subscribers to the Rare Earth hypothesis – the notion that so many factors have to be just right for life that living planets like our own are few and very far between.

Below: As the smallest planet, Mercury is most susceptible to the effects of chaotic changes

Yet even the chaos in our Solar System is still not complete. Over a human lifetime the path of the planets is predictable, but tiny interactions between worlds can build up to sizeable changes in the future. Just as the weather forecast begins to break down over timescales of more than a week, we can only predict the orbits of the planets for the next 40 million years or so – an astronomical heartbeat compared to the 4.6 billion years it has been around so far. It wouldn't take much to upset the whole system, and one planet is particularly susceptible to the ensuing melee. "There's a chance that Mercury could be ejected entirely," says Sutter. The orbit of the Solar System's smallest planet is constantly shifting round. The point at which it reaches its closest approach to the Sun – its perihelion – moves by 1.5 degrees every millennium. Jupiter's perihelion is moving too, and if the two ever get into the same rhythm then that could spell the end of Mercury. There's a one to two per cent chance its orbit will be seriously disrupted in the next few billion years. It could be ejected from the Solar System, or worse it could smash into the Earth. An inner Solar

> "Chaos theory gives us a mathematical tool to help us get a handle on what's going on" **Paul Sutter**

System without its first planet would itself become unstable. That could lead to Mars and Earth nudged into a calamitous collision. It just shows how much chaos theory matters.

We already have some evidence that the astronomical furniture can be significantly rearranged. Nearly a decade ago, astronomers spotted the first 'rogue' planets – worlds jettisoned from their home systems to wander the emptiness of space alone. There could be one Jupiter-sized orphan for every four stars in a galaxy like our Milky Way. Five per cent of Earth-sized planets would be able to cling onto any moons as they exited their system. Ejected planets form a big part of our best model of the formation of our Solar System. Astronomers running computer simulations discovered that you end up with a solar system that looks more like ours if you start with five giant planets instead of four. Except we don't have a fifth giant planet now. Either it went rogue or it is still languishing in the backwaters of the Solar System. That's because astronomers increasingly suspect there is a ninth planet marooned far beyond Neptune. This 'Planet Nine' could well be a failed rogue planet that was unable to exit the Sun's gravitational clutches entirely.

Even if the chaotic Solar System doesn't set us on a collision course with our neighbours, it could still have telling consequences for our climate. In 2017 researchers studying layers of rock in the Niobrara Formation in Colorado found a key piece of evidence that Earth and Mars interacted in an unusual way nearly 90 million years ago. At the

Below: Star forming regions – such as the Eagle Nebula – could be governed by chaos theory

©NASA/ESA

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Why is chaos theory important?

Solving it could help us unlock the secrets of the universe

What is chaos theory?

Chaos theory is a branch of mathematics that deals with patterns that repeat in complex systems. Often small changes in the system can soon grow to make a big difference later down the line.

Can it predict the future?

Not quite. With some systems – like a single planet orbiting a star – it is very easy to work out where the planet will be at any given time in the future. Yet as soon as you add a third object that reliable behaviour becomes unstable and much harder to predict. Chaos theory is all about looking for hidden patterns to get a better handle on future behaviour.

Didn't chaos theory appear in *Jurassic Park*?

It did. Jeff Goldblum's character Ian Malcolm is obsessed with chaos theory and predicts that it will be the downfall of the dinosaur park. In one scene in the jeep he uses droplets of water on the hand of paleobotanist Dr Ellie Degler to explain the theory.

Could understanding chaos help us with future tech?

It may be instrumental in effective quantum computers, which work by trapping and manipulating atoms using lasers. Those atoms move around chaotically, and understanding how that happens is important in being able to keep the atoms where you want them.

Could artificial intelligence (AI) help us?

Quite possibly. Earlier this year scientists trained a type of AI called a neural network on nearly 10,000 versions of the 'three-body problem'. It learned how to solve some of the test cases more effectively than a brute-force approach.

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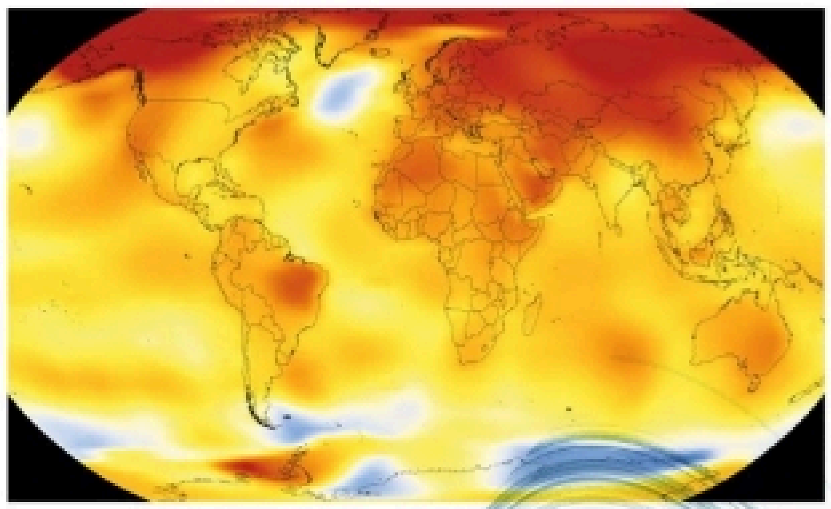
"We suspect that a lot more planets formed around the Sun - some on chaotic orbits" **Paul Sutter**

time there was a sea running through the middle of North America, and sediments falling to the sea floor were compressed into the rock seen there today. A team led by Professor Stephen Meyers of the University of Wisconsin-Madison found a difference in the clay levels between the layers of rock laid down over millions of years. A warmer, wetter climate leads to more clay being flushed into the sea from rivers than when the weather is drier. Alternating layers indicating wet and then dry climates were stacked up in a such a repetitive fashion that Meyer concluded there must be some cyclical phenomenon driving the changes. He points the finger at Mars and its ability to change the eccentricity of Earth's orbit. Eccentricity is a measure of how much a planet's orbit deviates from a circle. Any changes to this key value would change how much warmth the Earth receives from the Sun and provoke the knock-on climatic effects that come with that. It would also make our seasons unequal as the Earth would spend more of the year in one part of its orbit than another.

The Earth can be affected in other ways, too. The tilt of our axis can vary under the gravitational influence of the other planets. Right now we lean at 23.4 degrees from vertical, but that varies between 22.1 degrees and 24.5 degrees over a 41,000-year cycle. This also changes the amount of sunlight we receive, particularly in summer and winter when we are leaning towards and away from the Sun. If small changes build up in a chaotic way, this cycle may get out of rhythm. Equally, the Earth's axis moves around as our planet is wrenched by the Sun and Moon, tracing out a circle every 26,000 years or so. In the 1920s Serbian scientist Milutin Milankovitch combined all these effects and their regular effect on the Earth's climate, suggesting we go through periodic changes called Milankovitch cycles. They too may be susceptible to chaos.

As we move into a future where human-made climate change is going to bite harder and harder, it has never been more important to understand the full range of factors that can influence the way our atmosphere receives, stores and transports energy. A better understanding of chaos theory goes hand in hand with more accurate climate models and a better picture of how tiny changes in the layout of the Solar System can translate into big effects on our already-warming planet.



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Top: The Moon formed when a chaotically disrupted planet smashed into Earth

Above: A better understanding of chaos allows us to accurately predict climate

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THE RISE OF THE SPACEPORT

Increasing commercial space activity has called for more spaceports, and the world has answered

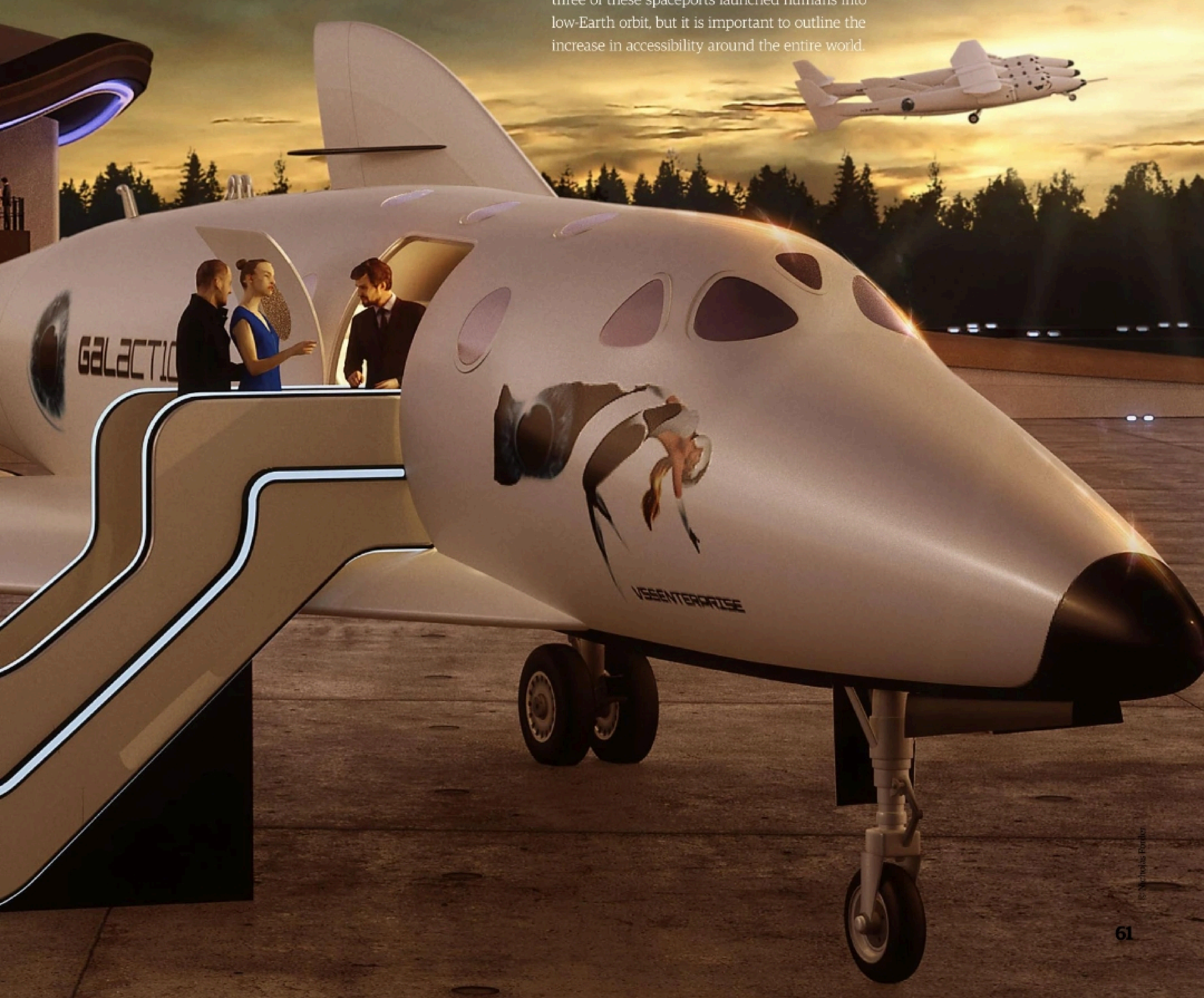
Reported by Lee Cavendish

Put yourself in the era of the 1950s and 1960s: space is a place exclusive to government agencies as the United States and the Soviet Union lock horns in the Space Race. Fast forward 50 years and space is now open to anyone and everyone, and commercial aerospace companies are making a real surge forward in making space tourism a real thing, no longer in the realm of science fiction.

Three major players in the game are SpaceX, Blue Origin and Virgin Galactic. All three are owned by their respective billionaire entrepreneurs Elon Musk, Jeff Bezos and Sir Richard Branson. These three companies are on the verge of offering flights into space for the average person – if they can afford the luxury – and the 2020s will undoubtedly see amazing milestones in this area. There are also many other aerospace companies around the world looking to capitalise on the commercial space industry, launching their own satellites into space without needing help from government rockets.

With this incredible increase in commercial activity in space, there has also been an increase in spaceports to accommodate such busy timetables. A spaceport isn't much different from an airport, but instead of putting things into the air, these ports are sending objects into space. There are two types of launches that set off from a spaceport, one being a vertical launch, which launches a classic two- or three-stage rocket, or a horizontal launch, which sends a spacecraft up to an altitude of roughly 15 kilometres (nine miles) on a jetliner before it detaches and continues its journey into space.

In 1963 there were 50 successful orbital launches from five different spaceports, including the United States' Vandenberg Air Force Base in California, Wallops Flight Facility in Virginia and the Kennedy Space Center in Florida, as well as the Soviet Union's Kapustin Yar Cosmodrome and Baikonur Cosmodrome, now in Kazakhstan. Compare that to 2018, where there were 112 catalogued launches from 22 different locations all over the globe. Only three of these spaceports launched humans into low-Earth orbit, but it is important to outline the increase in accessibility around the entire world.



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The United Kingdom is also now looking to create its first spaceports, with the introduction of a vertical launch spaceport in Sutherland, Scotland, and a horizontal launch spaceport in Cornwall, England. This development is stirring a lot of excitement around the country as it has great potential to improve the local economy and increase the national revenue from the space industry. "It is only recently that the demand for small satellite launches has been growing quickly. Five years ago the UK government recognised that the UK builds a large proportion of the world's small satellites, yet cannot launch them," Melissa Thorpe, head of engagement at Spaceport Cornwall, explains to **All About Space**. "The ability to have a sovereign launch capability and grasp the market will allow the UK to realise 10 per cent of the world's space economy. We will be providing a horizontal launch capability for the small satellite market with our partner Virgin Orbit, and we are in discussions with several other leading space companies for future projects."

But there is so much more to a spaceport than just its launch capability. As the former head of the Federal Aviation Administration's (FAA) commercial space office, George Nield, said: "Instead of just viewing spaceports as locations from which launches and reentries are conducted, I think it's also important to recognise that they can serve as focal points and technology hubs."

© NASA

"How many spaceports do we need?" Nield continued. "As many as it takes to ensure our national security, to maintain technological leadership, enable international competitiveness and provide inspiration for students and development of our aerospace workforce."

NASA and Russian Roscosmos have been at the forefront of manned space exploration since the 1960s, having settled the Space Race with a continuous presence in low-Earth orbit on board the International Space Station (ISS) along with greater international collaboration. As of 2018 NASA has outlined that it wants to return to the Moon, sending the first woman and returning a man, with another eye on visiting Mars. NASA has to do this on a $22.6 billion (£16.9 billion) budget, which is only 0.48 per cent of the United States' entire budget. With a plan like this constrained by tightened purse strings, the space agency has called for the intervention of private companies to take over presence in low-Earth orbit.

This call has been answered by multiple aerospace companies looking to make their presence known in space, and in doing so they are working hard to bring this experience to the people. One of the companies ready to make its mark in space is SpaceX, which has evolved remarkably under the leadership of Elon Musk. This company has formed and developed a great partnership with NASA through multiple cargo launches to the ISS using SpaceX's Falcon 9 reusable rockets. Boeing, another American aerospace company, is also going to send astronauts soon as part of NASA's Commercial Crew program.

SpaceX has performed a majority of its launches from the Kennedy Space Center, but is in the process of building the SpaceX South Texas Launch Site at Boca Chica Village in Texas. Assuming SpaceX is granted a spaceport license by the FAA, the company could soon be launching its next-generation heavy-duty reusable rocket – the Starship. This spacecraft and booster rocket

"The UK builds a large proportion of the world's small satellites, yet cannot launch them" **Melissa Thorpe**

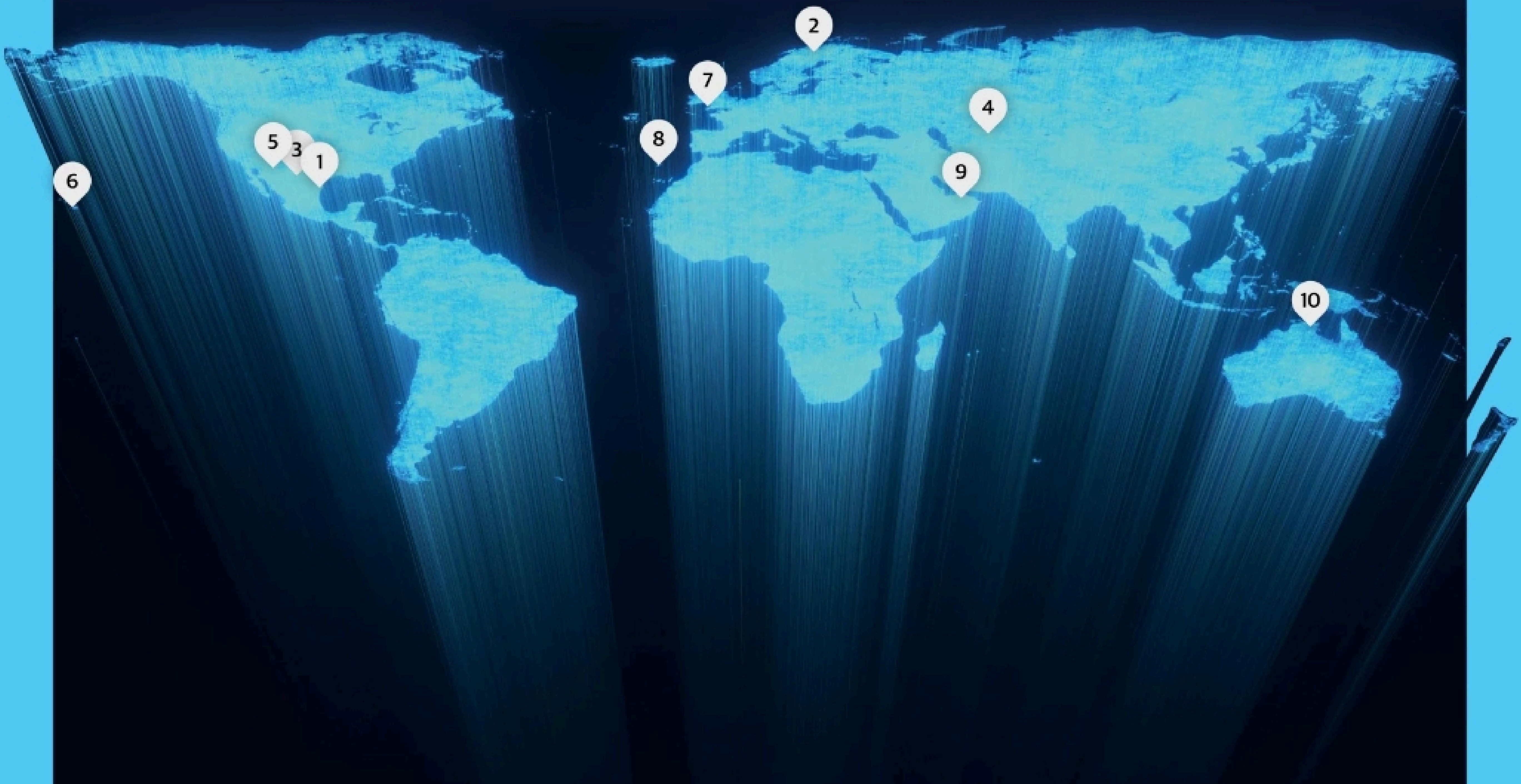
© NASA

Above: Dennis Tito (left) was the first space tourist to fund his own spaceflight in 2001

Left: Baikonur Cosmodrome has been the home of all astronauts launching to the ISS since NASA's Space Shuttle retired

The present and future of spaceports

With the rise of space tourism and commercial spaceflight, spaceports are popping up all over the globe



1

SpaceX South Texas Launch Site, United States

Also known as the Boca Chica Launch Site, SpaceX has had great support from the Texas state government and will continue with the construction of the spaceport and apply for an FAA license upon completion.

2

Spaceport Sweden, Kiruna

Active in the development of commercial manned spaceflight since 2005, Sweden's contribution to the commercial space industry is its Spaceport Sweden, located in Kiruna in the Arctic Circle, which will hopefully accommodate Virgin Galactic.

3

Blue Origin West Texas Launch Site, United States

As New Shepard continues to climb to new heights, Blue Origin will use its FAA-licensed launch site in the West Texas plains to continue to test and improve the world's first fully reusable vertically launched space vehicle.

4

Baikonur Cosmodrome, Kazakhstan

This Russian-leased spaceport has been launching astronauts and tourists for decades now, being the launch site used to send astronauts to the ISS. Roscosmos will continue to launch from this spaceport in the foreseeable future.

5

Spaceport America, New Mexico, United States

The world's first spaceport built for purely commercial operations is the new home of Virgin Galactic, who has recently announced its 'Gateway to Space', a beautiful communal area customers will use prior to their spaceflight.

6

Hawaii Air and Space Port

Hawaii is looking to improve its economic diversity by introducing a spaceport at Kona International Airport, and it may introduce suborbital point-to-point flights to the mainland United States that will shorten journey times for island commuters.

7

Spaceport Cornwall, United Kingdom

Spaceport Cornwall will accommodate horizontal launches. It will start with Virgin Galactic's sister company Virgin Orbit launching small satellites. However, it will have great facilities to accommodate space tourism adventures.

8

Portugal Space, Santa Maria

Portugal looks to crown its newly formed national space agency with the country's first spaceport in the Azores, which may potentially be let out to space tourism companies such as Virgin Galactic and Sierra Nevada.

9

Al Ain Airport, United Arab Emirates

The UAE Space Agency has big plans for space exploration and space tourism in the coming years, and it will be looking to use Al Ain Airport in a partnership with Virgin Galactic to perform spaceflights.

10

Arnhem Space Centre, Australia

Equatorial Launch Australia (ELA) is looking to build and operate Australia's first commercial spaceport in the northern region of the country. This will allow orbital and suborbital access to space for the country.

© Getty

© Virgin Galactic 2019

Above: Virgin Galactic and Under Armour recently showcased the spacewear for private astronauts

Below right: SpaceX's Starship could provide travel to the Moon, Mars and other destinations

combo is 50-metres (164-feet) tall and is capable of transporting passengers to the Moon and Mars.

In September 2018, Musk announced that someone has already bought tickets to the Moon on board SpaceX's Starship. Japanese billionaire Yusaku Maezawa, founder of Zozotown, will take a translunar flight as early as 2023. Neither Musk or Maezawa revealed how much the flight cost, and all that was divulged was that Maezawa has already made a substantial downpayment.

SpaceX also has plans to make Starship a point-to-point suborbital flight to destinations all around the world. In a promotional video posted by SpaceX in September 2017, it showed passengers boarding a Starship rocket that would take them from New York to Shanghai in just 39 minutes. In July 2019 it was also reported that the European Space Agency is drafting plans to start operating suborbital flights from Spaceport Cornwall that could start offering journeys from the UK to Australia that take just 90 minutes. This is a journey that would conventionally take roughly 20 hours by aeroplane.

Nield has stated that these kinds of suborbital point-to-point flights should start with short-distance journeys to nearby spaceports. But there needs to be a collective and overarching policy for everyone to adhere to. "We can articulate and document and then communicate this vision in a new policy," he said, pointing out that this whole process could lead to a new office of spaceports with the help of the FAA. "If we can get that up and running with the appropriate resources, staff and funding, that office could be a huge benefit in terms of being a focal point and an advocate."

Blue Origin will offer a unique experience, as passengers are jettisoned to the edge of the Earth to gaze upon its awe-inspiring curvature for prices yet unknown. Jeff Bezos' team reached some major milestones during testing of the reusable, vertically launched New Shepard rocket-capsule pairing in 2019 at its FAA-licensed West Texas suborbital test launch site. On 2 May 2019 New Shepard was jettisoned to a personal-record altitude of 106 kilometres (66 miles) while carrying 38 science experiments for various organisations, including NASA. After the launch the rocket made a safe vertical landing and the capsule was gently placed on the West Texas plains. When it is fully operational, this unique 18-metre (60-foot) rocket will take six people beyond the imaginary line of space known as the Kármán line, which lies at 100 kilometres (62 miles) in altitude. During this 11-minute vertical flight, tourists will be able to experience weightlessness for four of those minutes. After the event is concluded, the entire set-up can be refuelled, reconfigured and reused – and that will make the cost a lot cheaper.

The third billionaire space-tourism enthusiast is Sir Richard Branson with his Virgin Galactic. This offers an entirely different option of space tourism to SpaceX and Blue Origin. Virgin Galactic aims to take its passengers to space using the

What it takes to be a spaceport

The criteria for a spaceport is centred around the safety of operations with respect to its surrounding area

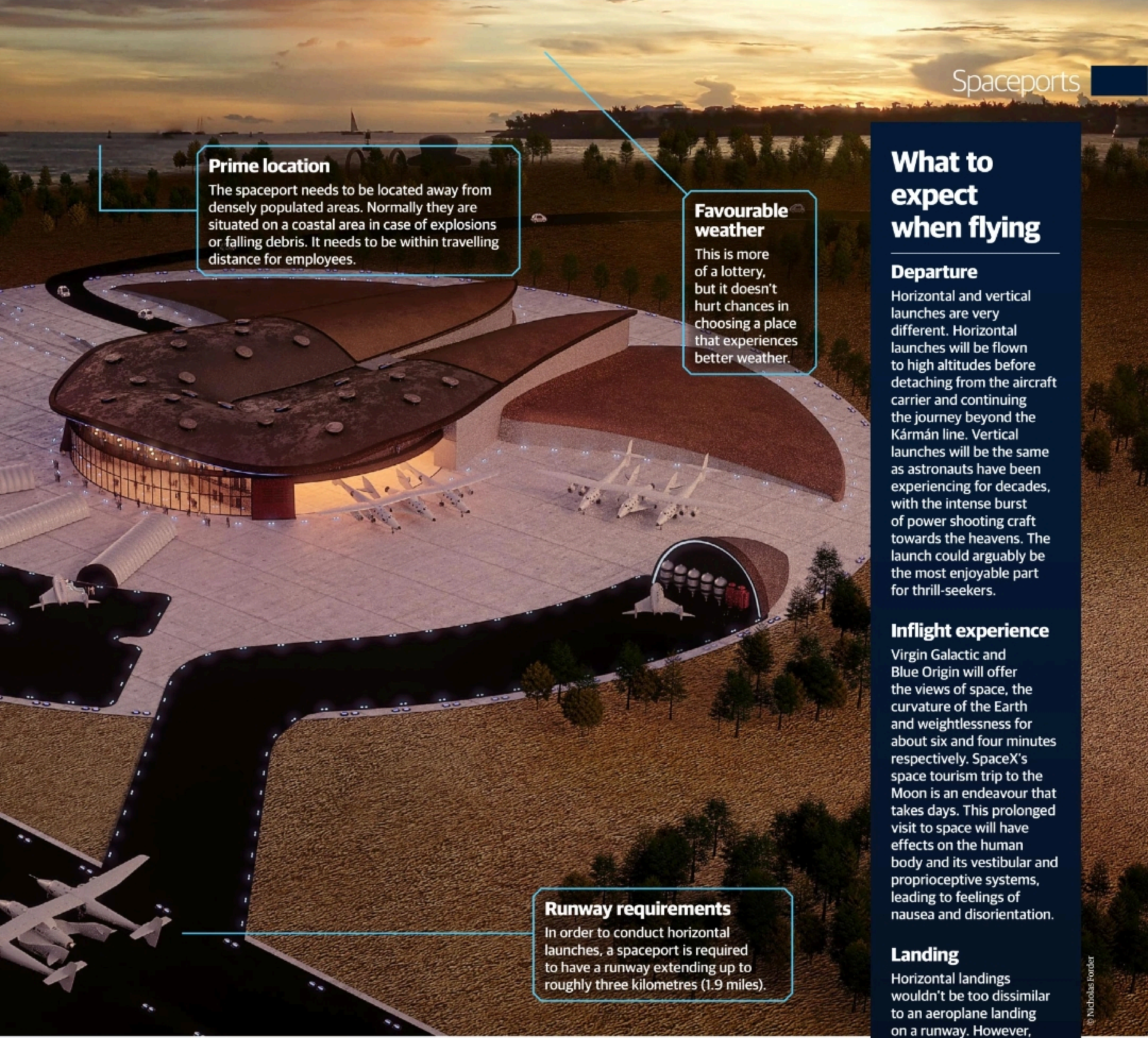
Airspace activity

Spaceplanes need a segregated airspace away from regular aeroplane traffic, as these planes are continuing to a different altitude.

Impact on the environment

The impacts in this case consist of the air and noise quality, as well as the storage of fuel and other materials.

> "I think it's also important to recognise that spaceports can serve as focal points and technology hubs" **George Nield**



Prime location

The spaceport needs to be located away from densely populated areas. Normally they are situated on a coastal area in case of explosions or falling debris. It needs to be within travelling distance for employees.

Favourable weather

This is more of a lottery, but it doesn't hurt chances in choosing a place that experiences better weather.

Runway requirements

In order to conduct horizontal launches, a spaceport is required to have a runway extending up to roughly three kilometres (1.9 miles).

© Nicholas Forder

reusable SpaceShipTwo spaceflight system, with the current operational model referred to as VSS Unity. This craft performs a horizontal launch from Virgin's spaceport using a custom-built aircraft carrier called WhiteKnightTwo. When the launch vehicle reaches an altitude of 15 kilometres (nine miles), SpaceShipTwo will detach and finish off the journey beyond the Kármán line.

This adventure has appealed to plenty of people already, and reportedly over 600 people from 60 countries have already placed deposits to be one of the first of Branson's high-flyers. The fare for such an adventure is to be within the region of £200,000 ($250,000) for the 90-minute spaceflight. It's a hefty price, but you could find yourself sitting next to some celebrities that have already bought their tickets, such as the

© SpaceX

What to expect when flying

Departure

Horizontal and vertical launches are very different. Horizontal launches will be flown to high altitudes before detaching from the aircraft carrier and continuing the journey beyond the Kármán line. Vertical launches will be the same as astronauts have been experiencing for decades, with the intense burst of power shooting craft towards the heavens. The launch could arguably be the most enjoyable part for thrill-seekers.

Inflight experience

Virgin Galactic and Blue Origin will offer the views of space, the curvature of the Earth and weightlessness for about six and four minutes respectively. SpaceX's space tourism trip to the Moon is an endeavour that takes days. This prolonged visit to space will have effects on the human body and its vestibular and proprioceptive systems, leading to feelings of nausea and disorientation.

Landing

Horizontal landings wouldn't be too dissimilar to an aeroplane landing on a runway. However, a vertical launch would lead to being parachuted down in your capsule into a desert, where you'd be collected and returned.

Arrival

Suborbital flights to the same destination don't require a passport, as you're not crossing any borders. However, point-to-point spaceflights will require your passport, for example on SpaceX's New York to Shanghai spaceflight. Returning from the ISS or the Moon may require you to fill out a customs declaration form, as even the Apollo astronauts had to do this.

How space affects both men and women

Prolonged weightlessness has significant effects on the human body, with subtle differences depending on sex

1 Motion sickness

MEN Not as susceptible as women to dizziness and lightheadedness when standing. Recent studies show that daily endurance training can counter this effect.

WOMEN Women appear to be more susceptible to dizziness and lightheadedness when standing. This is due to low blood pressure as the blood rushes away from the brain.

2 Visual impairment

MEN Experience significant visual-impairment issues while weightless, which causes worse hand-eye coordination and alters spatial awareness.

WOMEN At the time of this study, women did not exhibit the same significant visual-impairment problems as men.

3 Taste buds

MEN/WOMEN In weightlessness, fluids tend to shift from the lower part of the body to the upper part. This affects fluids in an astronauts face and even their taste buds. This lack of taste means a lot of meals in space require spice!

4 Kidney stones

MEN/WOMEN Men are more susceptible to kidney stones becoming a problem. This is due to increased likelihood of dehydration and the excretion of calcium from bones. UTIs are also a risk.

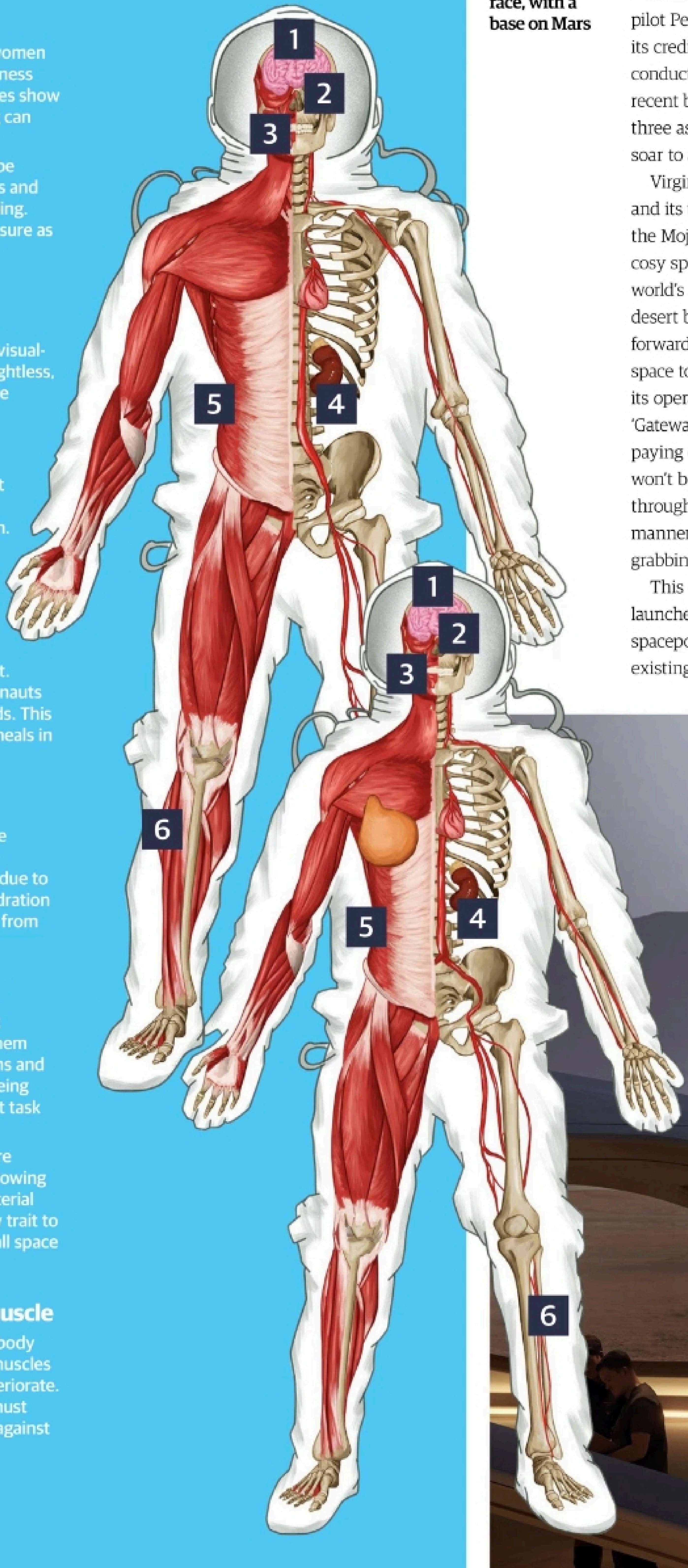
5 Immune responses

MEN Men have a less potent immune response, making them more susceptible to infections and putting them at risk of not being able to perform an important task when ill.

WOMEN Women have a more potent immune response, allowing them more immunity to bacterial and viral infections – a handy trait to have when confined in a small space with other astronauts.

6 Loss of bone and muscle

MEN/WOMEN Without the body working against gravity, its muscles and bones are known to deteriorate. For this reason, astronauts must exercise daily to counteract against this effect.



likes of Leonardo DiCaprio, Tom Hanks, Justin Bieber and many others.

Virgin Galactic has had highs and lows during testing. A chasmic depth was the crash of VSS Unity's predecessor, VSS Enterprise, in the Mojave Desert, California, on 31 October 2014. This disaster claimed the life of co-pilot Michael Alsbury, while pilot Peter Siebold was severely injured. Much to its credit, Virgin Galactic regrouped and has since conducted several successful test flights, the most recent being on 22 February 2019. This test saw three astronauts, including the first-ever passenger, soar to an altitude of 90 kilometres (56 miles).

Virgin Galactic recently relocated its employees and its testing and commercial operations from the Mojave Air and Space Port, California, to a cosy spot known as Spaceport America, the world's first fully commercial spaceport in the desert basin of New Mexico. This is a huge step forward for the company's plans to dominate space tourism, as this spaceport will be the hub for its operations. Virgin has recently announced its 'Gateway to Space', a swanky communal area for paying customers, a little like an airport lounge. It won't be long now before customers are strolling through spaceports in the same relaxed and calm manner as they would go through an airport, grabbing a coffee while they wait for their flight.

This could be the case for many horizontal launches, as Thorpe explains: "A horizontal-launch spaceport, such as ours, can operate from an existing airport – in our case Cornwall Airport

Below: Elon Musk and SpaceX want to create spaceships that can make humans an interplanetary race, with a base on Mars

Newquay. A spaceport requires separate legislation to allow flights and launches. This secondary legislation for spaceflight will give us the regulations required to launch satellites in the UK. We are an operational commercial airport, and we will be fully integrating space launches with Virgin Orbit into our everyday airline activities. We will be one of the only places in the world to do this."

Space tourism is not a new concept. The Russian space agency Roscosmos, in tandem with the American space tourism company Space Adventures, has been sending wealthier members of the public into space since 2001. The first one to exploit the market was American engineer and entrepreneur Dennis Tito. He had a luxurious week-long stay on board the ISS, which reportedly set him back £15 million ($20 million). Since then several super-rich clients have spent tens of millions to go to the ISS, and are continuing to do so, as two more tourists are due to launch in 2021. All of these missions were launched - and will continue to be launched - from the Baikonur Cosmodrome aboard a Soyuz rocket. An extreme percentage of the fee would likely go to launch costs, as the Soyuz rockets are not reusable.

The vast expense of such an adventure is the main reason why space tourism was deemed unreachable. But with this wave of emphasis on reusability and a string of promising tests performed by the aforementioned aerospace companies, other industries and organisations around the world are looking to become a part of this rapidly growing industry.

Expanding horizons beyond the constraints of the United States and Russia, spaceports are being lined up around the world. Europe could see the advent of spaceports in the United Kingdom, Sweden and Portugal. Even Australia and Asia are getting their own gateways to space in order to exploit this expanding market. In fact, in 2017 the UK House of Commons prepared a 'Space Sector Report' that stated that the current global space economy market is worth somewhere between £155 and £190 billion (approximately $200 and $250 billion), and is expected to reach £400 billion (around $530 billion) by 2030. This is over double the value in just ten years' time. With companies and organisations all over the world investing in this growing market, it is likely that space tourism could soon be a worldwide phenomenon.

> "We will be fully integrating space launches with Virgin Orbit into our everyday airline activities" **Melissa Thorpe**

© SpaceX

Celebrities in space

Leonardo DiCaprio

Not only has he bought a ticket to board Virgin Galactic's SpaceShipTwo, he also auctioned the seat next to him off for £1 million ($1.5 million), with all proceeds going to charity.

© JB Lacroix / Getty

Yusaku Maezawa

SpaceX's luxury trip to the Moon is going to the Japanese billionaire and a group of artists. This trip could take place as early as 2023.

© NurPhoto / Getty

Justin Bieber

Sir Richard Branson announced the Canadian pop sensation will be a Virgin Galactic astronaut in 2013. Bieber also seemed keen to shoot a music video in space as well.

© Randy Holmes / Getty

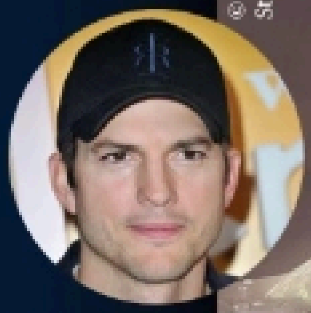
Tom Hanks

The Apollo 13 star is one of the hundreds of people to buy a ticket on SpaceShipTwo, forking out roughly a quarter of a million dollars.

© Allen Berezovsky / Stringer

Ashton Kutcher

The American actor became Virgin Galactic's 500th paying customer for a journey on SpaceShipTwo in 2012.



WHAT'S WRONG WITH MY TELESCOPE?

Views not clear, struggling with your mount or can't find an object? We've got the answers to your observing conundrums

Written by Mark Thompson

© Getty

Newcomers to astronomy are at some point likely to make that all-important purchase and buy a telescope. There are loads of models to choose from and the decision can be a daunting one. Seeking the advice of members of your local astronomy club or society is a wise one because they will have a wealth of experience and even equipment you could look at and maybe even try before you buy.

Whether you choose a reflecting telescope that uses mirrors to focus incoming starlight or a refractor that employs lenses, getting to this stage means you are well on the way to some incredible views of the night sky. Settling on a telescope and buying it is one thing, but setting it up and using it can present you with a whole world of problems that to the newcomer can be frustrating and even extinguish the spark of enthusiasm you once felt for the beauty of the night sky.

Don't worry – you're not alone. It is fair to say that anyone new to astronomy has more than likely experienced the trials and tribulations that you are facing. Being an amateur astronomer for nearly 30 years, I have seen and experienced most problems. I have captured some of the most common problems in this article and share with you pointers and possible solutions to get you going again.

PROBLEM #1

I cannot get a nice sharp image

What has happened? The telescope is lined up on the object, but when trying to focus it to get the image sharp, it is impossible to get a nice sharp image. Different eyepieces have been tried, but this does not make it any better.

The telescope may not be collimated

Solution: Telescope mirrors and lenses need to be aligned to give a nice sharp image. The process of getting them aligned is known as collimation. This is usually only a problem with telescopes that have mirrors in them such as reflectors or catadioptric telescopes. A great way to see if collimation is the problem is to point the telescope at a bright star and adjust the focus so that the star is out of focus and showing as a big blob.

Look closely and you will see a bright outer ring surrounding a dark central disc. If the dark disc is not in the centre of the bright ring then the optics are not aligned and you need to collimate. The steps to achieve this depend on the telescope you have, so check out the manual or find the guide for your telescope online and you should be able to get nice sharp images.

One thing to look for is the shape of the bright ring – the out-of-focus starlight – it should be circular. If it is spiked or triangular or another strange shape then the optics could be too tightly held in their holder and need adjusting.

There could be dew on your optics

Solution: It is not uncommon for dew or moisture to form on the telescope optics, especially if the telescope is stored indoors and you take it outside when it is cold. First, try to take the telescope outside in the afternoon so it cools down with the air. Dew can still form, and this is common in telescopes with lenses. Make up a tube from some sort of plastic so that it can sit at the 'front' end of the telescope near the main lens, effectively extending the length of the tube. It offers some protection to the lens, slowing down the formation of dew. You could also try getting heating straps or dew zappers that are designed for combatting dew, as these will definitely fix the problem.

The object may simply be too low in the sky

Solution: Light from objects low in the sky need to pass through a lot of gas in the atmosphere. This distorts the image we see, making it seem to dance around and often not 'stay' in focus. Try waiting for the object to get higher in the sky.

© Getty

PROBLEM #2

The telescope drive does not keep objects in the eyepiece for very long

What has happened? The telescope is pointing at the object I want to look at and the drive is switched on, but the object still drifts out of the eyepiece.

Check the telescope mount information is correct

Solution: If the mount is alt-azimuth – in other words it has an axis that is 'up and down' and another which is 'side to side' – then it will have a computer to control the motors on the two axes. Make sure that all the information like latitude, longitude, date and time are all set correctly. The manual will explain the exact steps depending on the type of mount.

Check the telescope is aligned correctly

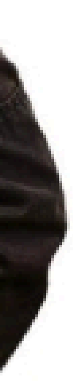
Solution: If the whole mount seems to be tilted at an angle, then it is an equatorial mount. If it is one of these then the whole mount needs to be accurately polar aligned, which means that the polar axis of the mount must point directly to the north celestial pole of the sky. The more accurate you are with this then the longer the objects will stay in the eyepiece. Some mounts have small telescopes in the polar axis that help you get them aligned, but for those that don't then I find drift alignment the best technique. If there is a computer control to the mount, make sure the correct drive speed is selected too.

Check any clutches are correctly set

Solution: Some mounts have switches to disengage and engage the motors. Make sure these are correctly set to ensure the motor actually drives the mount.

Check power!

Solution: This may seem obvious, but make sure there is power going to the telescope drive system. I have known power to get unplugged when a cable is kicked in the dark or for battery power to have drained in the cold of the night.



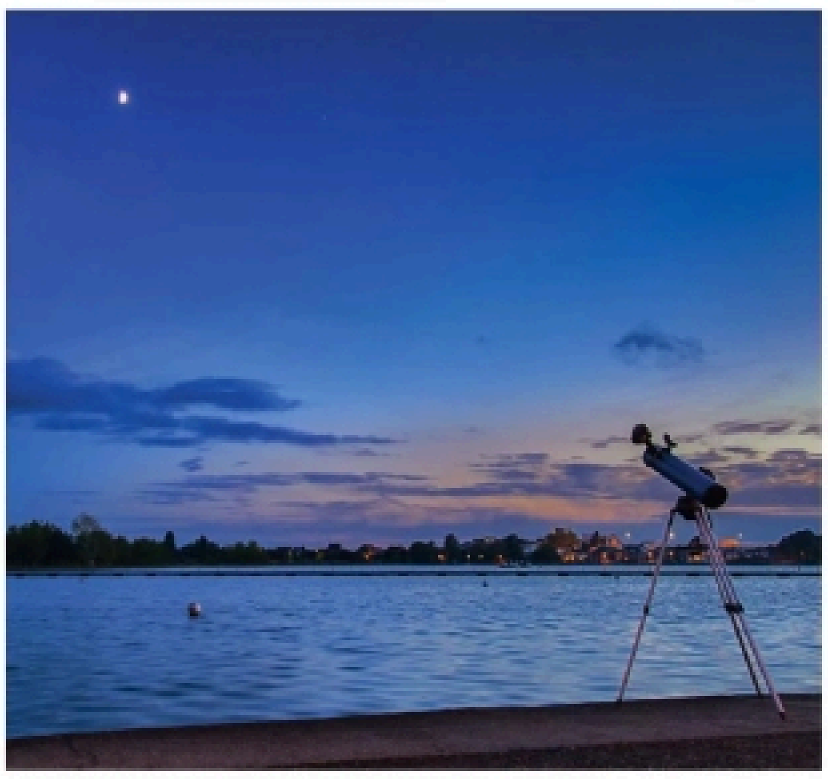
PROBLEM #3

The image through the telescope is not stationary; it seems to jump around quickly

What has happened? The telescope is pointing at the object I want to look at, but it does not stay still.

The object may be too low

Solution: When objects are low in the sky their light has to travel through a lot more gas in the atmosphere than when they are higher up in the sky. Their light also gets distorted and disturbed more by surface heat from the ground, and this can all make the image dance around. Wait until it gets a bit higher, or if it is lower in the west, then try observing it earlier tomorrow night.



The wind may be too strong!

Solution: It will not necessarily impact the light, but what it may do is impact the telescope! Whatever type of telescope you have, it has the purpose of collecting light and magnifying it to give a 'zoomed-in' image. A telescope will not only magnify the light, but will also magnify any wobbles or shakes in the telescope system. If it's a bit blustery then any buffeting of the telescope will be magnified. You could try moving the telescope to a place where it is more sheltered from the wind, make sure all bolts and screws are tight or even upgrade to a more sturdy mount.

© Getty

> "When objects are low in the sky their light has to travel through a lot more gas in the atmosphere"

Are you touching the mount or telescope?

Solution: Just like the disturbance from the wind, if you are touching the telescope then this – magnified several hundred times – can easily cause the image to jump around. The solution is simple: stop touching the telescope or mount.

PROBLEM #4

I cannot find the object I am looking for

What has happened? I can see things through the eyepiece and the image is nice and sharp, but I cannot line it up on objects I am looking for.

The finder telescope is not lined up to the main telescope

Solution: The finder telescope is a smaller telescope attached to the side of the main telescope. On some instruments it may be a laser-pointer finder attached to the main instrument, but the function is the same. By lining the finder instrument up on the object you are looking for, then the main telescope will also be pointing at it.

The trick is that the finder must be pointing in the same direction as the main telescope. If it is not, finding things will be a lot harder – if not impossible. To check if this is the issue, during the daytime, point the main telescope at an easily identifiable object like an aerial or chimney. Do not use trees because they tend to move in the wind sometimes. Now look through the finder telescope and adjust the screws holding it in place until it too is pointing at the object you were looking at in the main telescope. Go back and check that the main telescope is still pointing at it, centre it if needs be and then fine-tune the finder.

> "The trick is that the finder must be pointing in the same direction as the main telescope"

Computerised telescopes might not be set up correctly

Solution: If your mount is computerised, make sure the location – latitude and longitude – date, time and, if present, hemisphere switch – north or south – are correctly set.

PROBLEM #5

I cannot see anything through the telescope

What has happened? The telescope should be lined up on an object and the lens cap is off, but I cannot see anything through the eyepiece.

© Getty

The sky has gone cloudy!

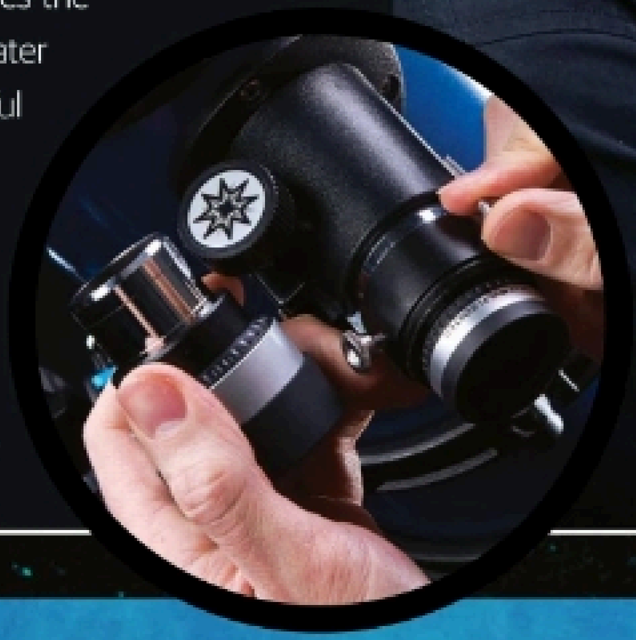
Solution: Cloudy skies often thwart the amateur astronomer, but it is not unusual to be midway through an observing session only to find unexpected clouds appear seemingly from nowhere. I speak from experience that, on occasion, unexpected clouds can cause objects to miraculously vanish from view while peering down the eyepiece. It is worth a glance upwards to make sure a clump of cloud has not appeared.

Your eyes are not dark-adapted

Solution: The human eye is designed to be able to see in the dark, but this dark adaption is not instant. It takes time for your eyes to adjust to seeing in the dark. In fact, it can take up to 40 minutes for the process to complete. There are two changes that take place when you are immersed in a dark environment. The iris opens up in just a matter of seconds; this is to allow more light to enter the eye. There is also a change to the chemicals in your eyes to make them better at seeing in the dark, but this can take quite some time, as long as 40 minutes. If you have just popped out from a normally illuminated room, it is quite possible that your eyes are not yet adjusted to the darkened environment. Give your eyes time to adjust and you will be amazed at what you can see.

The eyepiece is too powerful

Solution: Changing the eyepieces in the telescope will change the magnification, but this comes with a drawback. Increasing the magnification also increases the darkness of the image and it is possible to increase the magnification so much that the image becomes too dark to be useful. There is a really handy rule of thumb to work out the maximum magnification of a telescope… Take the aperture in millimetres and double it. This gives you the maximum useful magnification before the image starts to get too dark. To work out the magnification of the eyepiece and telescope combination, divide the focal length of the telescope by the focal length of the eyepiece. This gives the magnification. If it is greater than the maximum useful magnification, then try another lower power eyepiece, which will be denoted by a longer focal length, usually measured in millimetres.



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Need more info?

Mark's website has a great section to help you with many of the processes outlined in this article. Head over to: **markthompsonastronomy.com**

ASK Space

Our experts answer your questions

Did you know?

The most distant quasar detected, ULAS J1342+0928, contains the oldest known supermassive black hole in the universe.

COSMOLOGY

What came into existence first: black holes or galaxies?

Galaxies, or the ancestors of galaxies as we know them today, likely came first. More specifically, stars – first-generation stars – likely formed first and produced the first 'artificial' light in the universe, before any black hole could form.

The first generation of stars likely formed just a few hundred million years after the Big Bang, hosted by dark matter mini-halos. We still don't know what dark matter is, but we surely think we owe our very existence to it. Without dark matter stars would not be able to form, and the universe as a whole would never witness the invention of chemistry by the supernovae explosions of the first stars and the subsequent possibility of biology that followed.

In principle the first black holes – with masses of a few Suns – were actually a result of what was left of massive first-generation stars after they exploded and produced some of the oxygen we are breathing right now.

Interestingly enough, it is possible that some of the first supermassive black holes – with masses of almost one million-times the Sun – could have formed by a direct collapse of clouds of gas, essentially without ever becoming a star. However, it turns out that you need stars or a galaxy in relatively close proximity in the very early universe to give rise to the conditions necessary for these extraordinary events to happen. All in all, we think that first-generation stars came first, but rapidly led to the formation of the first black holes and the first supermassive black holes.

Dr David Sobral is a reader in astrophysics at Lancaster University in England, researching the primitive universe and how the first galaxies formed

© ESA

Space agencies are always looking to create better space analogues in unusual Earth-based locations

With early supernovae explosions came new elements to form more complex stars and galaxies

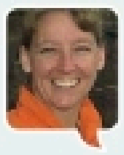
© NASA/ESO

SPACE EXPLORATION

How does the new Artemis spacesuit differ from the suits used on the Apollo missions?

We've been working for a long time to build spacesuits that will do the job on the Moon and going onto Mars. My job is to take a basketball, shape it like a human, keep them alive in harsh environments and give them the mobility to do their job. One of the things we've looked at is trying to reduce the space [around the chest area], make a smaller display control unit and get the shoulders to where astronauts have a lot more mobility to move.

The astronaut is now able to do a cross-reach and get across the suit, as well as reach overhead, which astronauts can't do today and couldn't do in the Apollo program. In addition to that, because this is the first time we've got to build a suit specifically for a planetary exploration mission, we've got a lot more mobility in the lower torso. There is a waist bearing, three bearings on the legs as well as a flexion extension joint at the waist. This gives the astronaut a lot of capability to move around and to do whatever task they need to do for science and maintenance on the planetary surface.



Amy Ross is an advanced spacesuit designer at NASA's Johnson Space Center in Houston, Texas

SPACE EXPLORATION

How is exploring caves a good analogue for exploring space?

Cooperative Adventure for Valuing and Exercising human behaviour and performance Skills, or CAVES, is the best analogue training astronauts have ever participated in. It does start with the environment, which offers similar stressors as human spaceflight – isolation, confinement, real risk, lack of privacy, reduced communication and resources, difficult rescue and so on.

Both are risky environments, both require safety to be your top priority and situational awareness needs to be high. But all that is just the fertile terrain over which you can create a real scientific exploration mission, using mission operations very similar to space operations. This is key. Using real speleological scientific exploration and documentation, not just a fake science-fiction, space-looking exercise, which may well be appealing to the public, but would be laughed at by astronauts.

CAVES prepares astronauts to become more effective and safe teams by exposing them to a realistic space analogue expedition. The analogies offered by the environment, the technical progression and the scientific and operational set-up are instrumental, but also the professional and personal qualities of the support team, which act as mentors and role models: explorers of the underworld forming explorers of other worlds.

Loredana Bessone is head of analogue field testing and exploration training at the European Space Agency

Right: NASA administrator Jim Bridenstine announced the new Artemis spacesuit in October 2019

© NASA

ASK Space

Our experts answer your questions

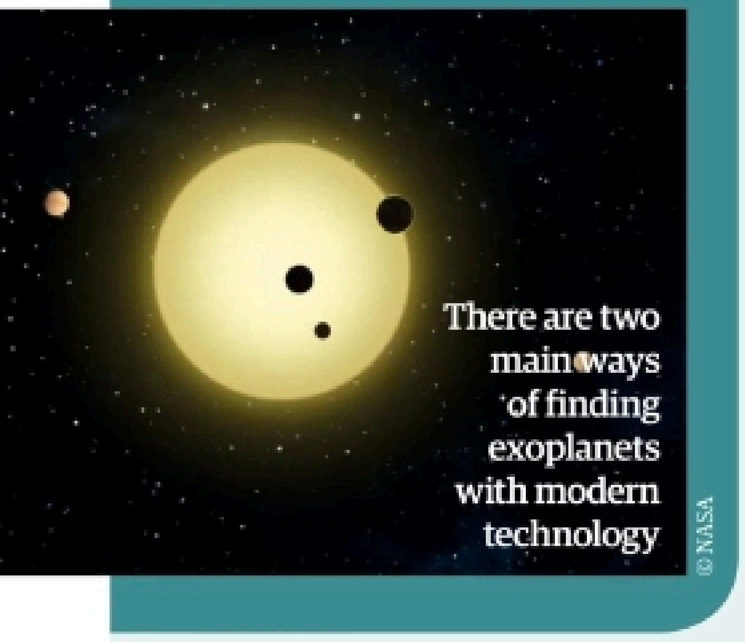
SPACE EXPLORATION

What methods are used to detect exoplanets?

The radial velocity technique relies on measuring stellar wobbles introduced by an unseen exoplanet orbiting a star. Both the star and planet orbit their common centre of mass, which is offset somewhat from the centre of the star. When searching for this wobble, we can measure the speed at which the star is moving towards or away from us over its orbit thanks to the Doppler effect. Starlight can appear slightly bluer or redder when the star is moving towards or away from us. The effect is very small and not perceptible to the eye, but by precisely measuring the spectrum of a star with spectrographs, we can pick out these radial velocity shifts.

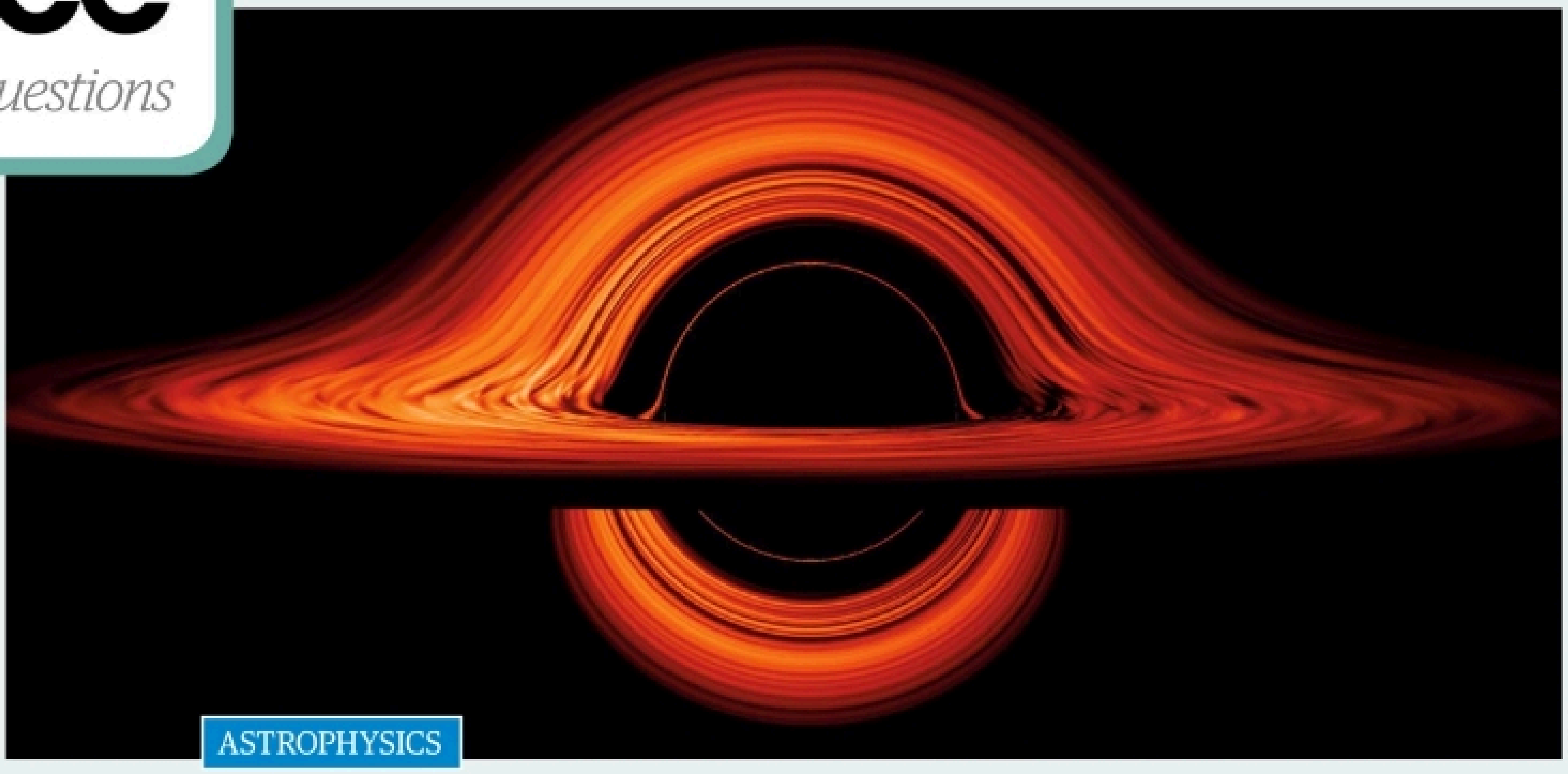
The most prolific discovery technique is the transit method. When a planet's orbit is aligned with our line of sight to the star, the planet will pass directly in front of the star once per orbit and block some starlight. We find transiting exoplanets by measuring the brightness of a star and looking for telltale periodic dips. The shape of these transit events tell us the size of the exoplanet and the inclination of its orbit, so along with information from radial velocity measurements, we can measure its true mass and density.

Dr Benjamin Rackham is a member of the exoplanet-hunting team, Project EDEN



There are two main ways of finding exoplanets with modern technology

© NASA



© NASA

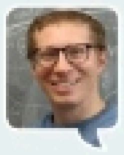
Above: A black hole's intense gravity alters light coming towards it to create a 'photon sphere'

ASTROPHYSICS

What is a 'photon sphere'?

One hundred years ago, Einstein truly became a household name when his theory of relativity was first tested and confirmed by experiments. Einstein predicted that light passing by a massive object should get deflected by gravity, and that this effect could even be detected by measuring the apparent location of stars near the Sun during a solar eclipse. For the Sun, this deflection is less than a thousandth of a degree. For a black hole, with its much stronger gravitational field, the light ray can get bent by 360 degrees or more.

Imagine shining a laser pointer at a black hole. If you point it right at the black hole, the light will get swallowed by the horizon. If you point it to the side, it will get deflected by the black hole's gravity, but still reach your friend on the other side. But as you point the laser closer and closer to the black hole's edge, there is a point where the light just barely doesn't get captured, but also doesn't escape. Instead it just orbits around and around in a perfect circle. This is what we call the 'photon sphere' of a black hole. For non-spinning black holes, the photon sphere radius is 50 per cent bigger than the horizon radius, but for rapidly rotating black holes, the photon sphere snuggles right up against the horizon, allowing light to orbit many times without falling in, and without falling out.



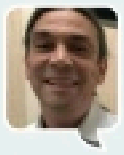
Dr Jeremy Schnittman is a research astrophysicist at NASA's Goddard Space Flight Center, Maryland

SOLAR SYSTEM

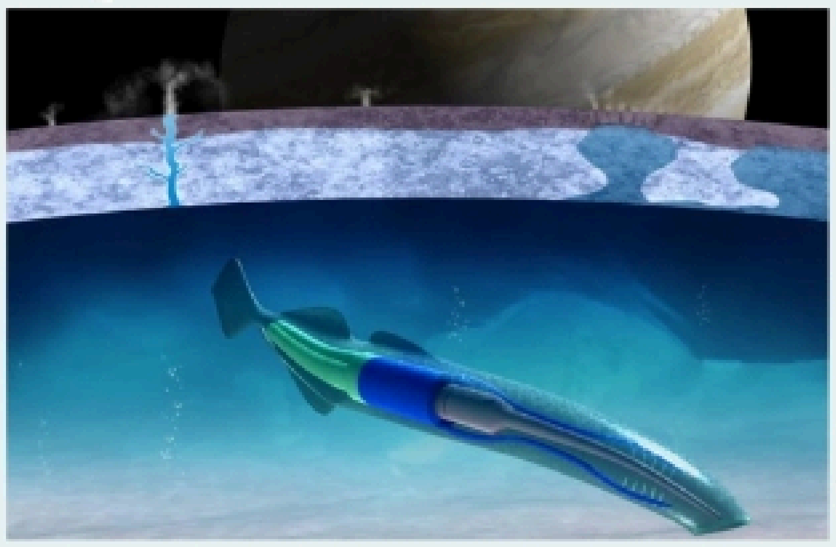
What evidence have we found that supports the theory that there could be life on Europa?

Jupiter's moon Europa is believed to have a global ocean about 20 kilometres (12 miles) beneath its icy surface. Evidence includes strange geology, including cracks formed by large tides raised by Jupiter as Europa orbits. Also, Europa has a magnetic field that is likely generated in a salty subsurface ocean as the moon orbits through Jupiter's powerful magnetic field.

On Earth, essentially everywhere there is liquid water, there is life. Life as we know it requires three so-called 'ingredients' that might exist at Europa. The first ingredient is liquid water, a solvent that promotes chemical reactions. Europa's ocean could be Earth-like in its temperature and salinity. The second ingredient is the chemical elements from which organic molecules are built: carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulphur. Europa probably formed with these elements, gaining more as comets and asteroids impacted the moon through time. The third ingredient is energy to power life. On Earth, most energy for metabolism comes from sunlight, which drives photosynthesis. However, photosynthesis can't operate in Europa's ocean, because sunlight can't penetrate the thick ice cover. Other Earth microorganisms are powered by chemical energy, where molecules chemically react to form new molecules while storing energy. We need to better understand whether Europa's ocean can support life powered by chemosynthesis. Future spacecraft exploration can indicate whether Europa's ocean has the three ingredients for life, and therefore could be considered potentially habitable.



Dr Robert Pappalardo is project scientist on NASA's Europa Clipper mission, set to launch in 2025



© Adrian Mann

Right: Astronomers have observed evidence for favourable conditions under the icy crust of Europa

ASTROPHYSICS

Does dust help or hinder star formation?

Dust has an important role in star formation. It protects the molecules in the dense gas from the ultraviolet photons emitted by the massive young stars. Without dust, the molecules would be broken and the atoms ionised. In star-forming regions there are a lot of these young stars formed in nearby clouds. The newly formed stars can thus reduce the capability to form new stars. This is why dust has an important role to help the formation of dense molecular clouds by protecting them.

In contrast, while not hindering star formation, dust is limiting our capability to measure star formation. When spectroscopy is not available – which is often the case in very distant galaxies – we estimate the amount of stars formed per year in a galaxy from the ultraviolet light they emit, since it comes mainly from massive short-lived stars. The main problem is that dust is very efficient at absorbing the ultraviolet light.

We have to correct for this phenomenon. We can deduce the energy absorbed by it using the thermal emission of this cold dust. This is usually a few tens of degrees above absolute zero and even less for distant galaxies because of the redshift effect. This is why far-infrared and submillimeter telescopes, which probe the emission of these cold bodies, are so important for understanding the star formation history in the universe.

Dr Matthieu Bethermin is a assistant astronomer at Laboratoire d'Astrophysique de Marseille, France

Did you know?

The largest existing submillimetre telescope, the James Clerk Maxwell Telescope, is located on Mauna Kea in Hawaii.

The 'Pillars of Creation' are famous for their striking pillars of dust, with new stars born within

©NASA/ESA/The Hubble Heritage Team

What's in the sky?

In this issue...

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Our pick of the best books, apps, software and accessories for astronomy and space fans

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

Source : Wikipedia Commons © Tomruen

2 JAN
Messier 41 is well placed for observation in Canis Major

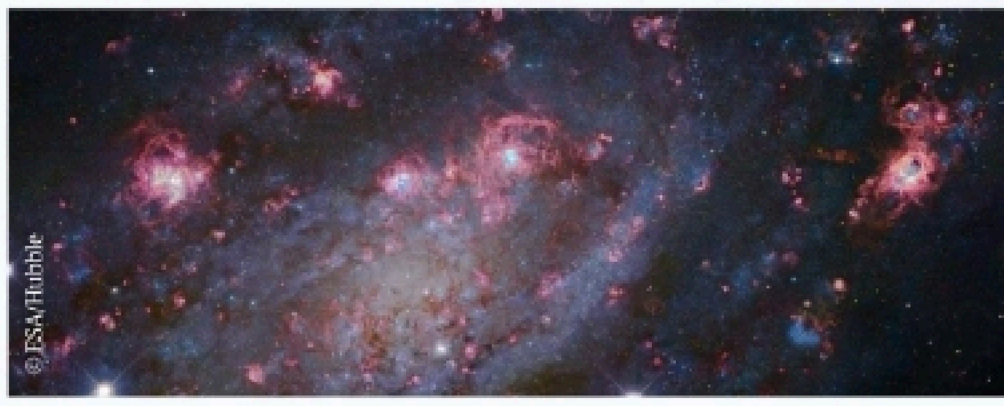
4 JAN
The Quadrantids reach their peak of 120 meteors per hour

12 JAN
The Moon and Messier 44 make a close approach in Cancer

Source : Wikipedia Commons © Giuseppe Donatiello

15 JAN
Asteroid 511 Davida is well placed for observation in Gemini, glowing at magnitude 9.6

15 JAN
Open cluster Messier 47 is well placed for observation in Puppis at magnitude 4.4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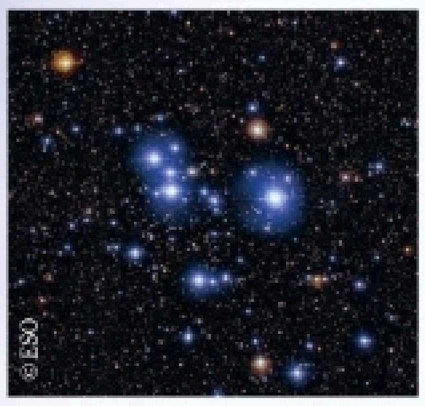
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21 JAN
Asteroid 5 Astraea is well placed for observation in Cancer at magnitude 8.9

Source : Wild © Astronomical Institute of the Charles University

Jargon buster

Conjunction

A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)

Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)

This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude

An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition

When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

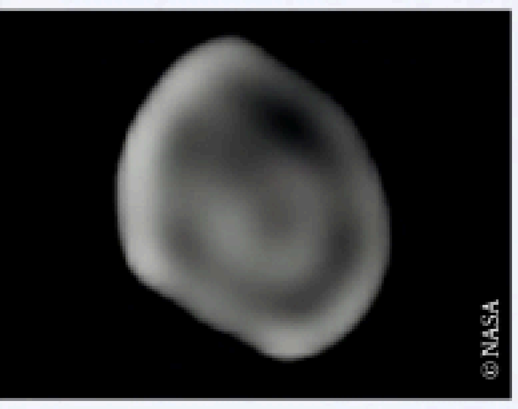
Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

10 JAN

Penumbral lunar eclipse is visible from Africa, Oceania, Asia, Europe and Northern America

© Getty


© NASA

15 JAN

Spiral galaxy NGC 2403 is well placed in Camelopardalis, glowing at magnitude 8.9

20 JAN

Conjunction between the Moon and Mars in Ophiuchus

20 JAN

The Moon and Mars make a close approach, passing within 2°11' of each other in Ophiuchus

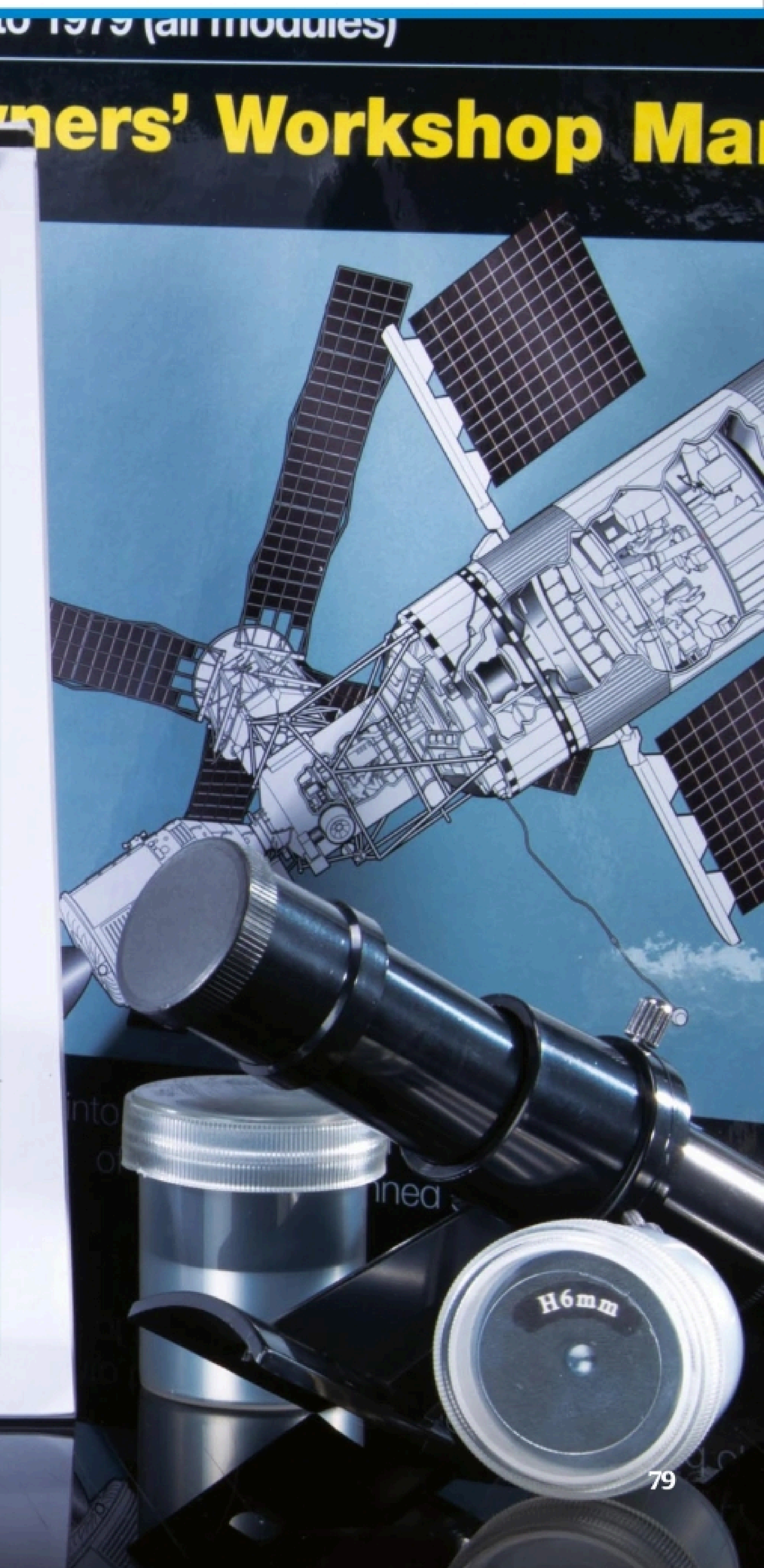
28 JAN

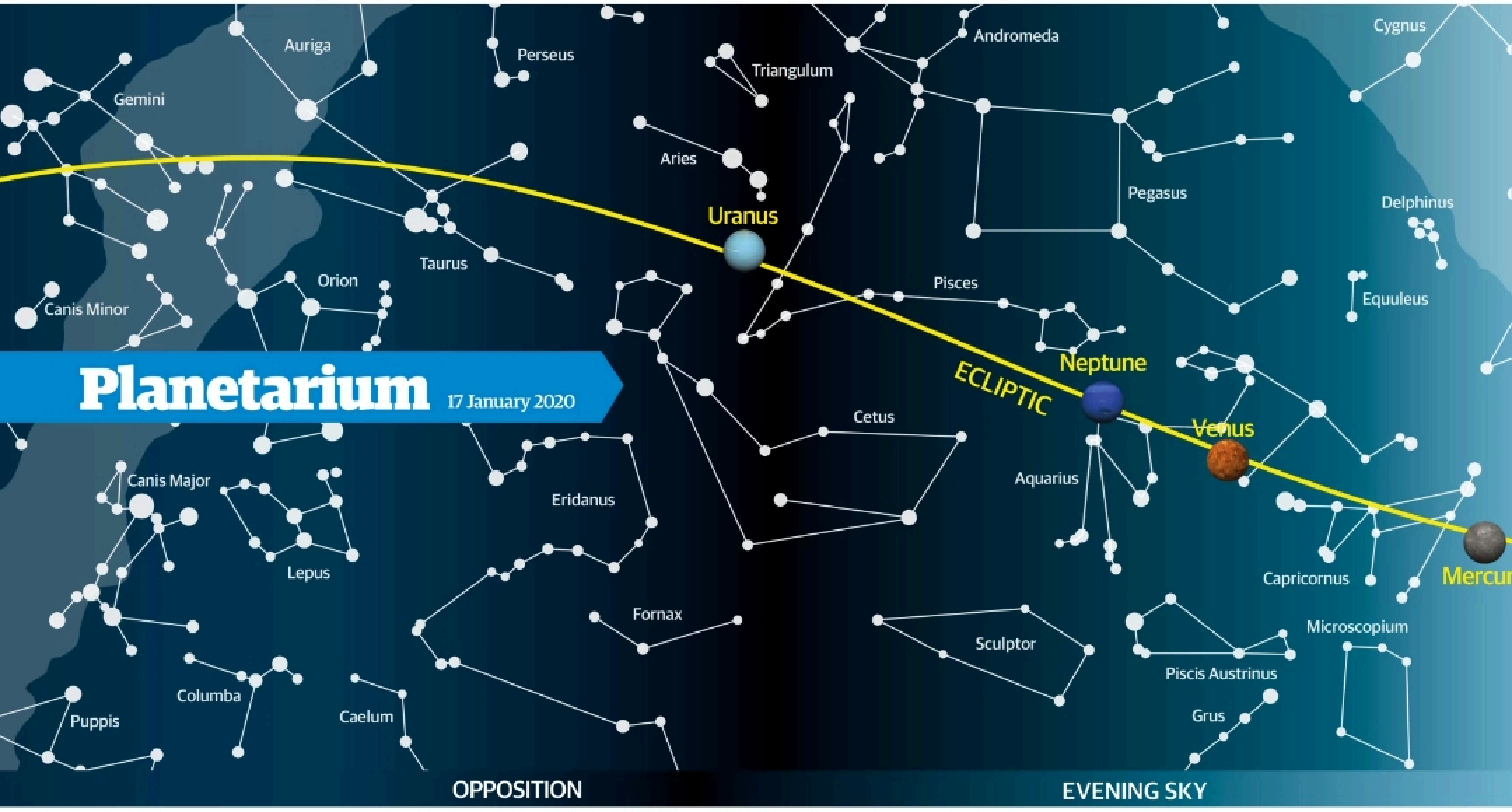
Conjunction between the Moon and Venus in Aquarius

28 JAN

The Moon and Venus make a close approach, passing within 3°49' of each other in Aquarius

Naked eye
Binoculars
Small telescope
Medium telescope
Large telescope



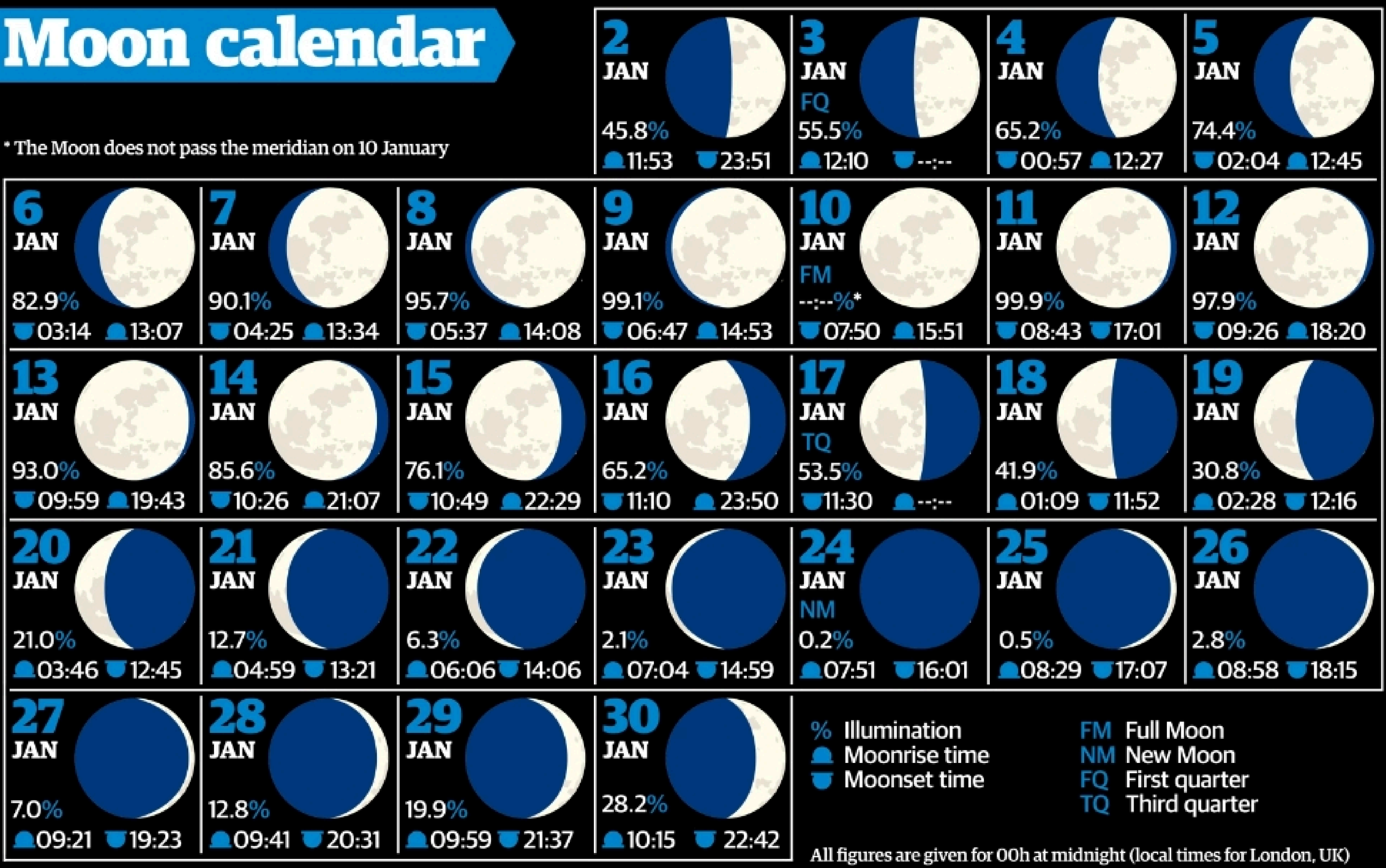


Planetarium

17 January 2020

Moon calendar

* The Moon does not pass the meridian on 10 January

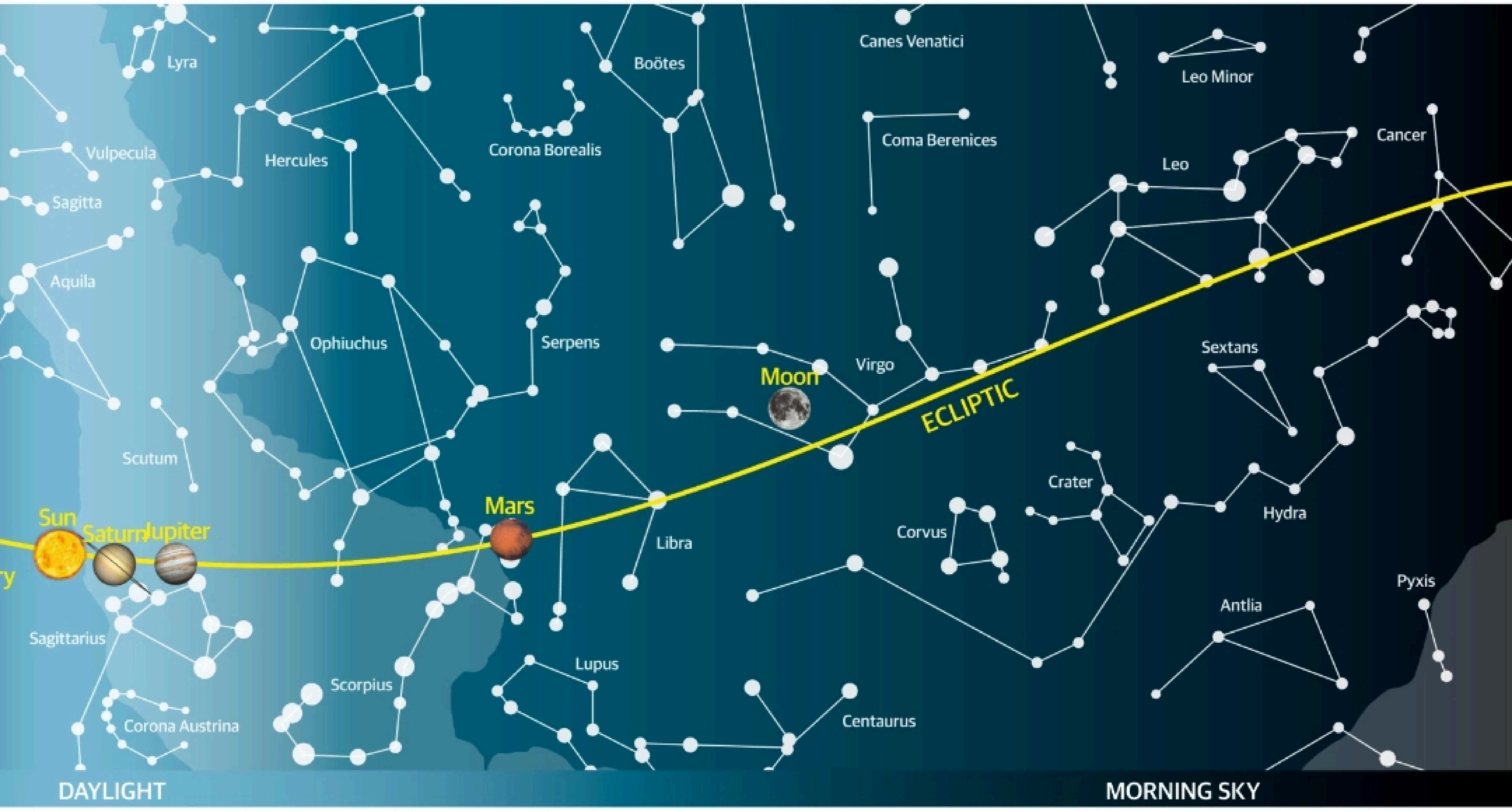


			2 JAN 45.8% ◓11:53 ◒23:51	**3** JAN FQ 55.5% ◓12:10 ◒--:--	**4** JAN 65.2% ◒00:57 ◓12:27	**5** JAN 74.4% ◒02:04 ◓12:45
6 JAN 82.9% ◒03:14 ◓13:07	**7** JAN 90.1% ◒04:25 ◓13:34	**8** JAN 95.7% ◒05:37 ◓14:08	**9** JAN 99.1% ◒06:47 ◓14:53	**10** JAN FM --:--%* ◒07:50 ◓15:51	**11** JAN 99.9% ◒08:43 ◒17:01	**12** JAN 97.9% ◒09:26 ◓18:20
13 JAN 93.0% ◒09:59 ◓19:43	**14** JAN 85.6% ◒10:26 ◓21:07	**15** JAN 76.1% ◒10:49 ◓22:29	**16** JAN 65.2% ◒11:10 ◓23:50	**17** JAN TQ 53.5% ◒11:30 ◓--:--	**18** JAN 41.9% ◓01:09 ◒11:52	**19** JAN 30.8% ◓02:28 ◒12:16
20 JAN 21.0% ◓03:46 ◒12:45	**21** JAN 12.7% ◓04:59 ◒13:21	**22** JAN 6.3% ◓06:06 ◒14:06	**23** JAN 2.1% ◓07:04 ◒14:59	**24** JAN NM 0.2% ◓07:51 ◒16:01	**25** JAN 0.5% ◓08:29 ◒17:07	**26** JAN 2.8% ◓08:58 ◒18:15
27 JAN 7.0% ◓09:21 ◒19:23	**28** JAN 12.8% ◓09:41 ◒20:31	**29** JAN 19.9% ◓09:59 ◒21:37	**30** JAN 28.2% ◓10:15 ◒22:42			

% Illumination
◓ Moonrise time
◒ Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	10 JAN	17 JAN	24 JAN	31 JAN
MERCURY	100%	100%	100%	90%
VENUS	80%	80%	80%	70%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

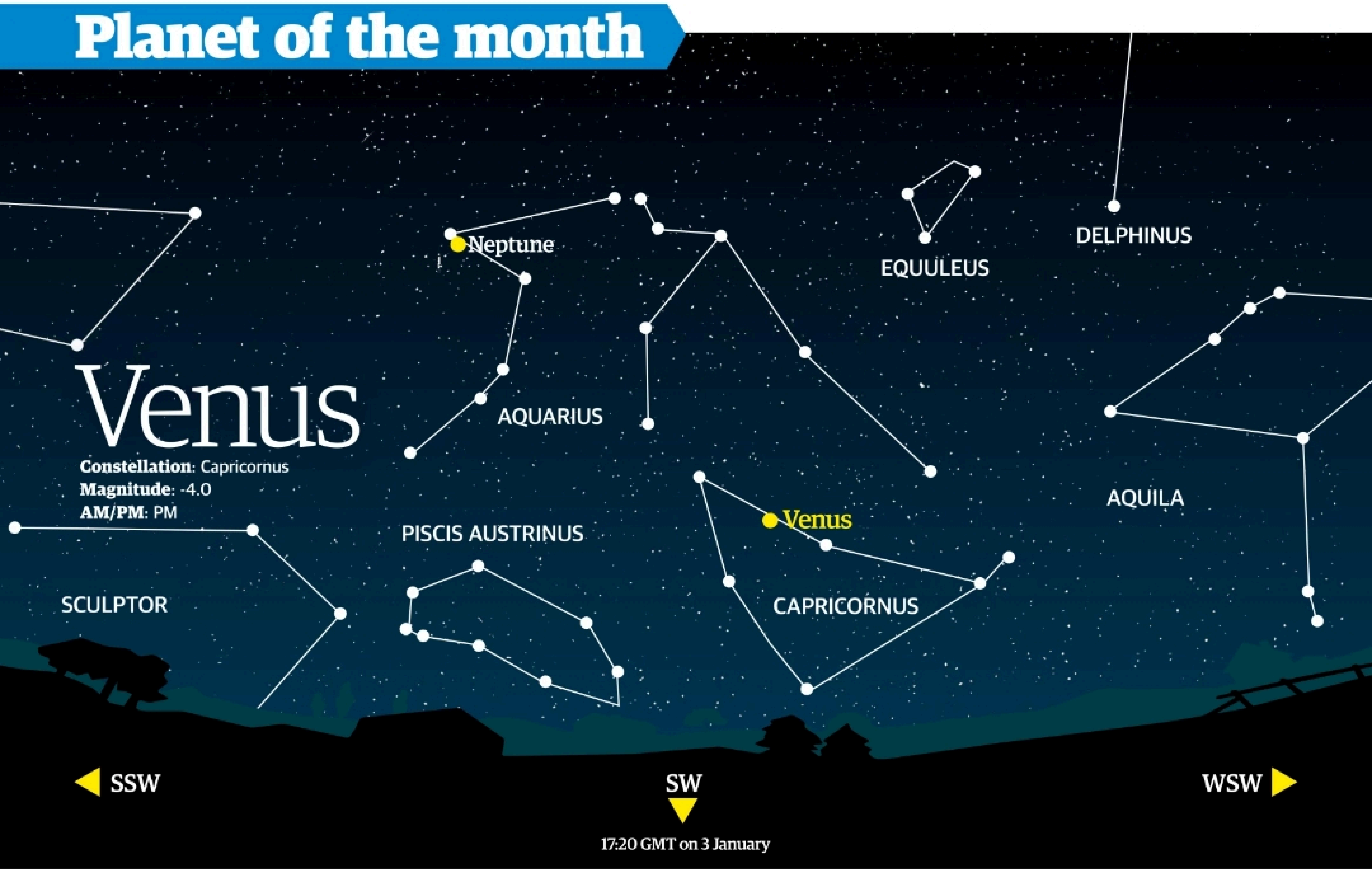
All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	3 JAN	18h 32m 03s	-24° 40' 30"	Sagittarius	-1.0	07:59	15:27
	10 JAN	19h 21m 23s	-24° 02' 02"	Sagittarius	-1.3	08:16	15:53
	17 JAN	20h 11m 09s	-22° 10' 18"	Capricornus	-1.3	08:25	16:28
	24 JAN	21h 00m 24s	-19° 02' 59"	Capricornus	-1.1	08:27	17:10
	31 JAN	21h 47m 16s	-14° 45' 53"	Capricornus	-1.0	08:21	17:54
VENUS	3 JAN	21h 18m 28s	-17° 35' 47"	Capricornus	-4.0	09:59	18:59
	10 JAN	21h 52m 01s	-14° 44' 44"	Capricornus	-4.0	09:48	19:22
	17 JAN	22h 24m 26s	-11° 35' 09"	Aquarius	-4.0	09:36	19:44
	24 JAN	22h 55m 50s	-08° 11' 28"	Aquarius	-4.1	09:21	20:05
	31 JAN	23h 26m 23s	-04° 38' 05"	Aquarius	-4.1	09:06	20:27
MARS	3 JAN	15h 49m 21s	-19° 41' 59"	Libra	1.6	04:43	13:18
	10 JAN	16h 09m 00s	-20° 42' 55"	Scorpius	1.5	04:42	13:04
	17 JAN	16h 28m 58s	-21° 35 '41"	Ophiuchus	1.5	04:40	12:50
	24 JAN	16h 49m 13s	-22° 19' 47"	Ophiuchus	1.4	04:38	12:38
	31 JAN	17h 09m 44s	-22° 54' 41"	Ophiuchus	1.4	04:35	12:27
JUPITER	3 JAN	18h 29m 52s	-23° 10' 24"	Sagittarius	-1.8	07:46	15:35
	10 JAN	18h 36m 51s	-23° 05' 29"	Sagittarius	-1.8	07:25	15:15
	17 JAN	18h 43m 46s	-22° 59' 28"	Sagittarius	-1.8	07:04	14:55
	24 JAN	18h 50m 35s	-22° 52' 27"	Sagittarius	-1.9	06:42	14:35
	31 JAN	18h 57m 16s	-22° 44' 30"	Sagittarius	-1.9	06:21	14:15
SATURN	3 JAN	19h 32m 19s	-21° 41' 32"	Sagittarius	0.5	08:39	16:48
	10 JAN	19h 35m 50s	-21° 34' 10"	Sagittarius	0.5	08:14	16:24
	17 JAN	19h 39m 21s	-21° 26' 29"	Sagittarius	0.5	07:49	16:01
	24 JAN	19h 42m 51s	-21° 18' 34"	Sagittarius	0.5	07:24	15:38
	31 JAN	19h 46m 18s	-21° 10' 28"	Sagittarius	0.6	06:59	15:15

This month's planets

Evening star Venus makes its presence known alongside Saturn and Uranus, while early risers can enjoy the rest the Solar System has to offer

Planet of the month



Venus

Constellation: Capricornus
Magnitude: -4.0
AM/PM: PM

17:20 GMT on 3 January

This month Venus will be a genuinely beautiful sight in the sky after dark. The world often – and very wrongly – called 'Earth's Twin' will become visible very soon after sunset as an eye-catching, metallic glint high in the south-southwest. As twilight deepens and the sky darkens it will get brighter and brighter until it looks like a lantern blazing in the sky, a stunning 'evening star' far brighter than any of the stars around it and brighter than anything else in the whole sky apart from the Moon. Shining at magnitude -4.0 all through the month, Venus will be so bright that not even the ghastly orange glow of light pollution in a town or city will be able to hide it, and if you can get to somewhere truly dark you'll be amazed by just how bright Venus looks. Nothing can compare to it.

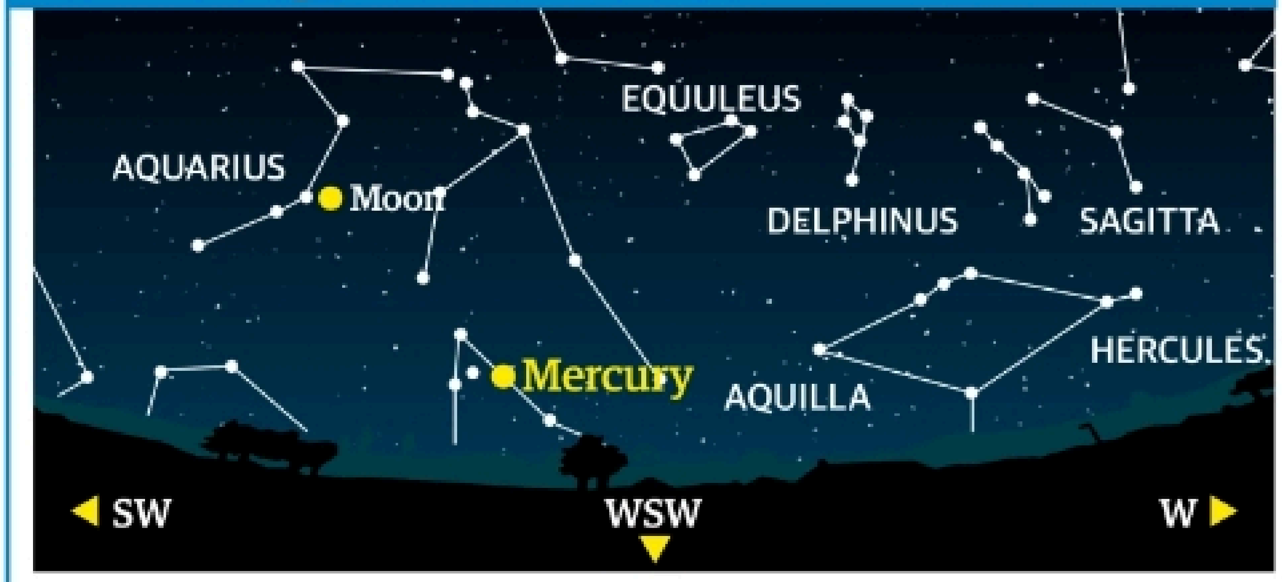
It's ironic that such a beautiful, serene sight is in reality such a frightening world. Venus, the second planet out from the Sun, is like a world invented for a dystopian science-fiction film. Its atmosphere of thick, curdled carbon dioxide would be lethally poisonous to us, and the incredible pressure on its surface would crush us too. Droplets of acid fall through its sky, but evaporate in the terrible heat long before reaching the ground. It will not be a holiday destination any time soon.

By the end of January, when it will have wandered across Capricorn's border into Aquarius, this beautiful but brutally hostile planet will be setting more than three hours after the Sun, and so it will be visible in a dark sky, not just in the twilight. Look at it through a pair of binoculars or a small telescope at this time and it will be a dazzling sight, juddering slightly as it drops slowly through the layers of air churning above the horizon.

Cross your fingers for clear evening skies during the last few days of January, because we'll have an opportunity to see the crescent Moon gliding past Venus, the two objects forming a striking sight after sunset. On the 27th a fingernail clipping-thin Moon will shine to Venus' lower right. The following evening the Moon, now a slightly wider crescent, will lie to the left of Venus, just five degrees from it. On this evening the dark part of the Moon's face should be lit by the pale, ghostly lavender-blue glow of 'Earthshine', and that should be the case on the following evening too, the 29th, when the Moon will have moved on along its track to shine to the upper left of Venus.

This month's planets

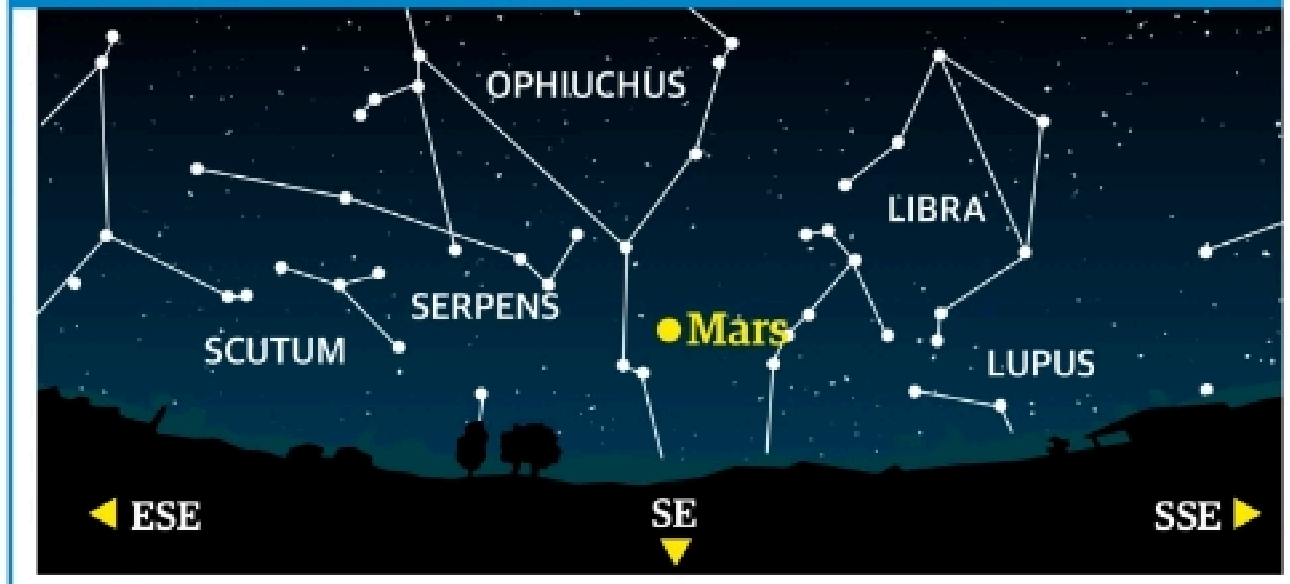
Mercury 17:00 GMT on 27 January



Constellation: Sagittarius
Magnitude: -1
AM/PM: PM

Mercury begins the month too close to the Sun to be visible, and by the end of the month will only have moved far enough away from it to provide only the most optimistic and careful observers with any hope of catching sight of it very low in the southwest after sunset, to the lower right of much brighter Venus.

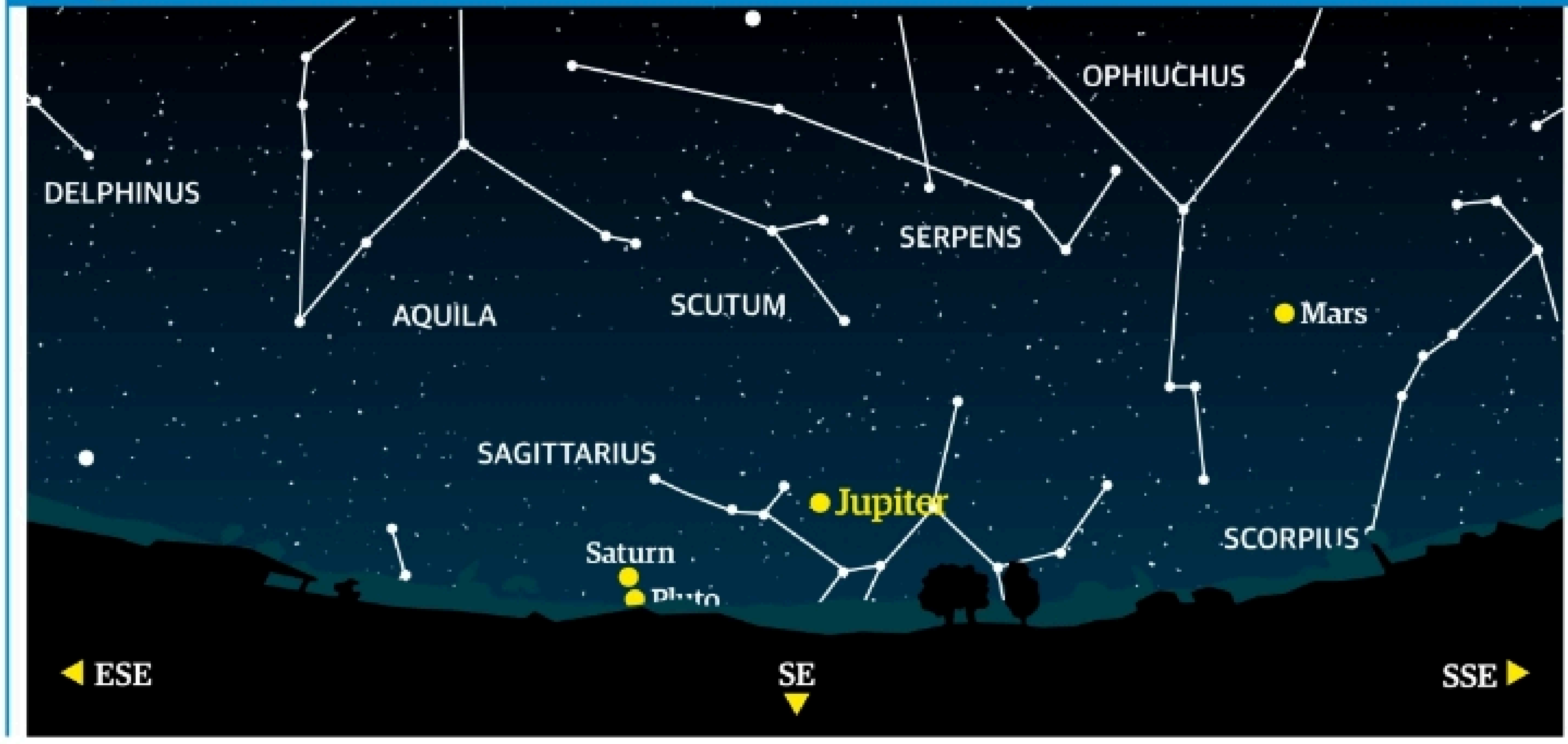
Mars 06:00 GMT on 29 January



Constellation: Libra
Magnitude: 1.6
AM/PM: AM

Looking like an orange star among the fainter stars of Libra, at the start of the month Mars rises around four hours before the Sun. It will remain an easy naked-eye object throughout the month, creeping closer to our star. A waning crescent Moon passes Mars in the morning sky between 20 and 21 January.

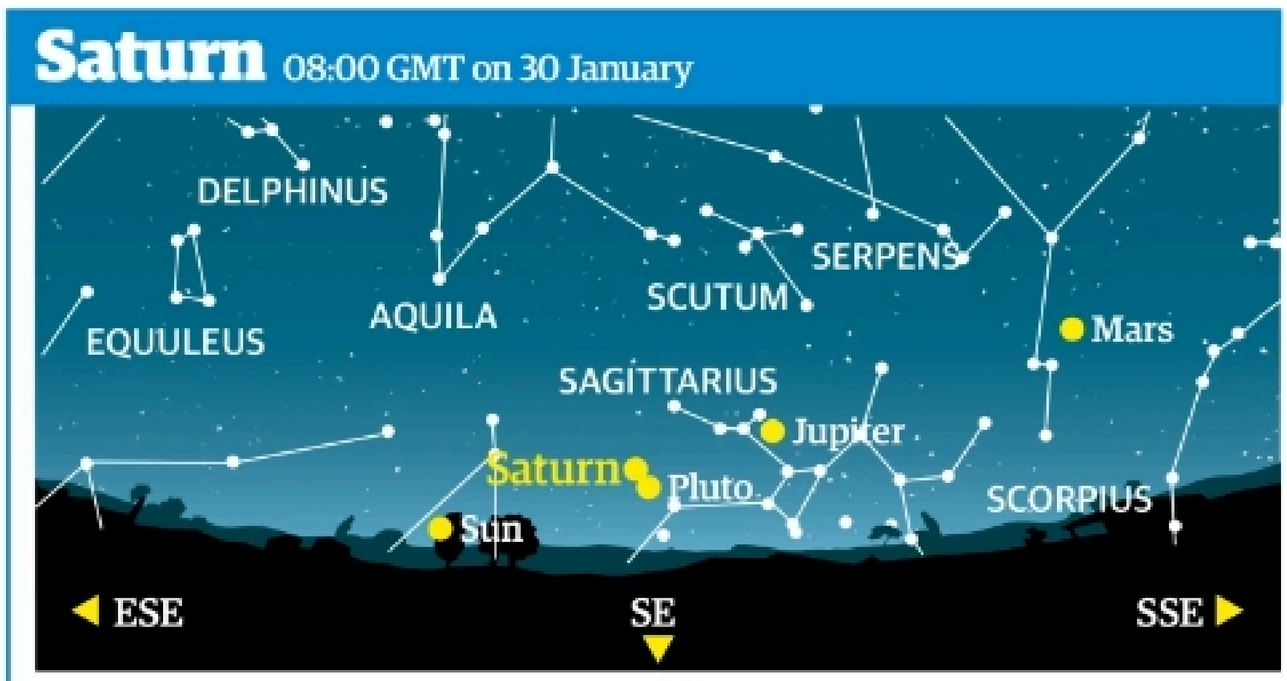
Jupiter 07:30 GMT on 25 January



Constellation: Sagittarius
Magnitude: -1.8
AM/PM: AM

If you enjoy the sight of Jupiter, the largest of all the planets in our Solar System, blazing like a blue-white jewel in the sky, then I'm afraid this isn't going to be a good month for you. At the start of January Jupiter is too close to the Sun to be seen, but as the days pass it will slowly pull away from it. Even so, by the end of January Jupiter will still be so close to the Sun that it will be a challenge to find and observe; you might just glimpse it incredibly low in the southeast before dawn, but only if there are no trees, buildings or hills on the horizon in that direction.

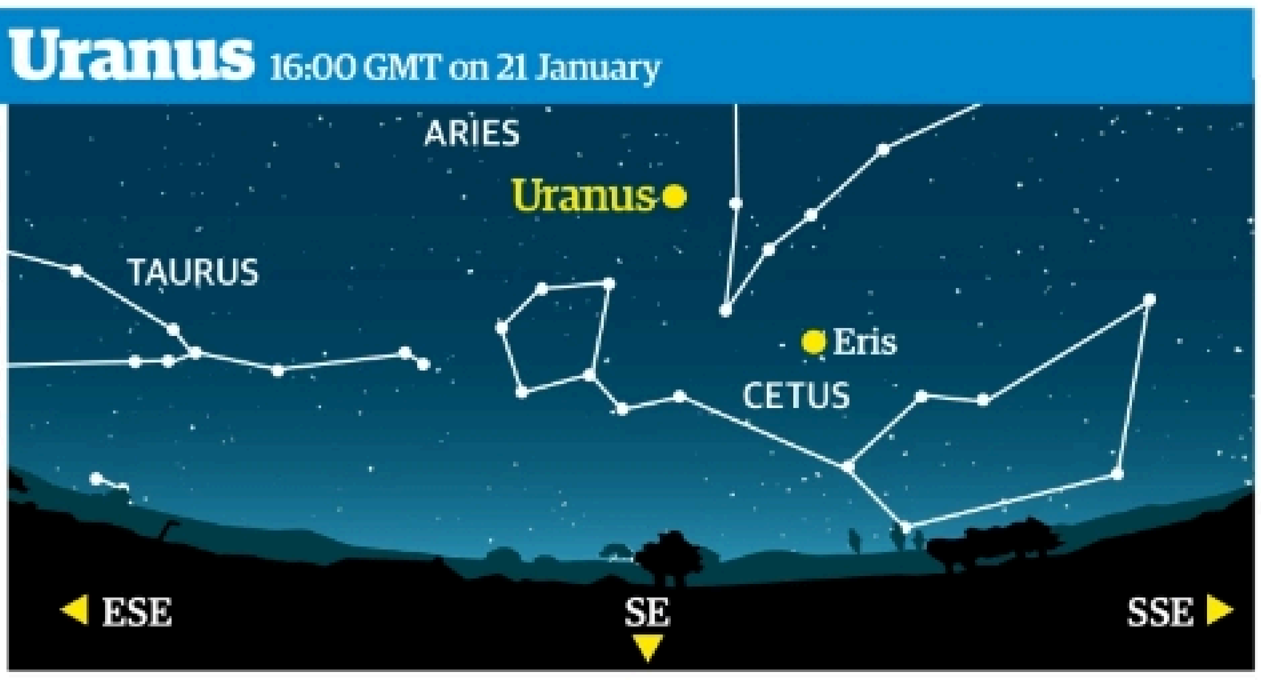
Saturn 08:00 GMT on 30 January



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: AM

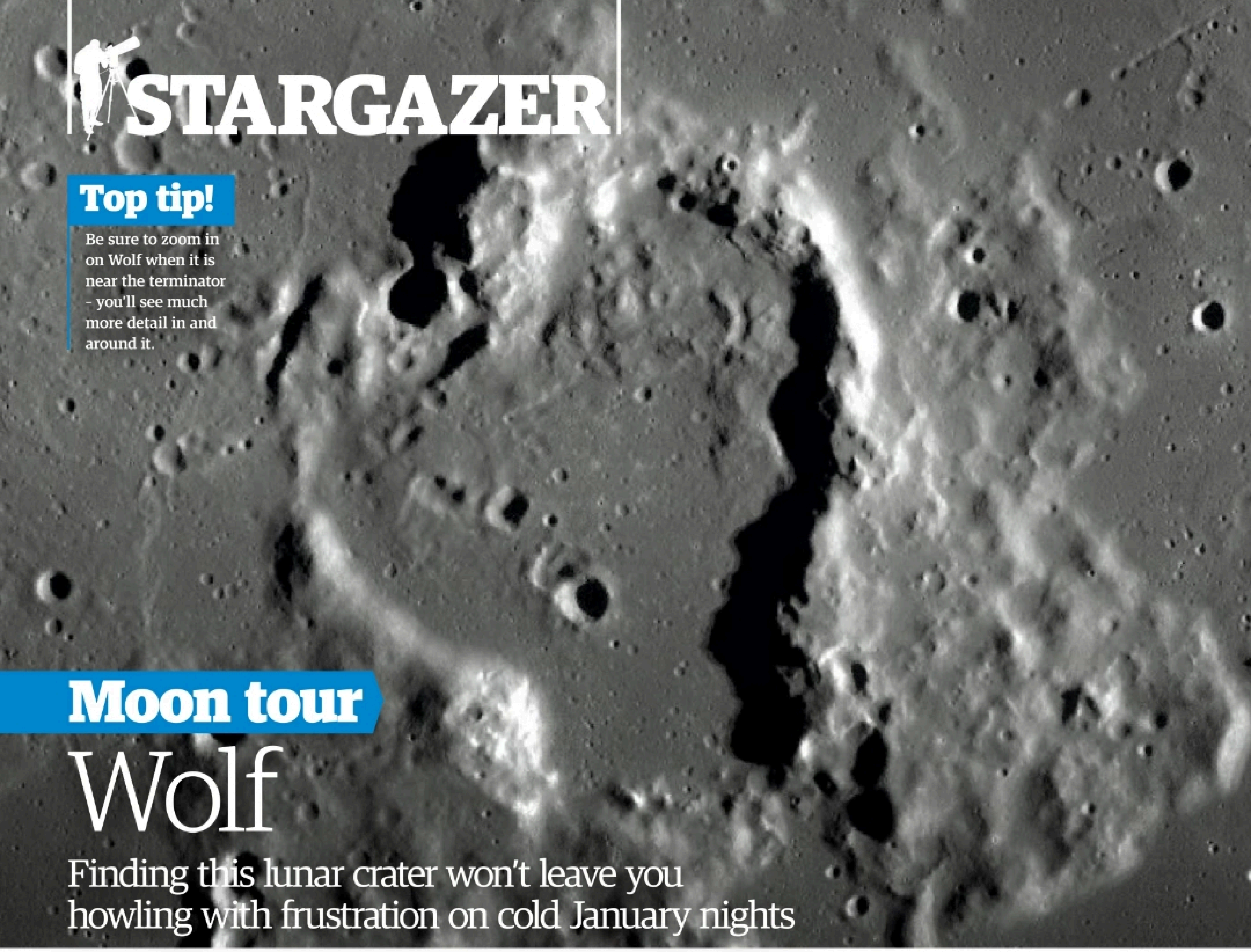
At the start of the month Saturn is simply too close to the Sun to be seen – and it actually gets worse as the days pass and it creeps closer to our star, and then behind it. By the end of January Saturn will have emerged from behind the Sun, but will not have moved far enough away from it to be easily visible.

Uranus 16:00 GMT on 21 January



Constellation: Aries
Magnitude: 5.7
AM/PM: PM

This is a good month to look for and observe Uranus in the sky. It will be a faint 'evening star'. At the start of the month the seventh planet out from the Sun is already high in the south as darkness begins to fall, and it will remain visible in the sky, arcing from east to west, until it sets in the early hours of the next morning.



Top tip!

Be sure to zoom in on Wolf when it is near the terminator – you'll see much more detail in and around it.

Moon tour

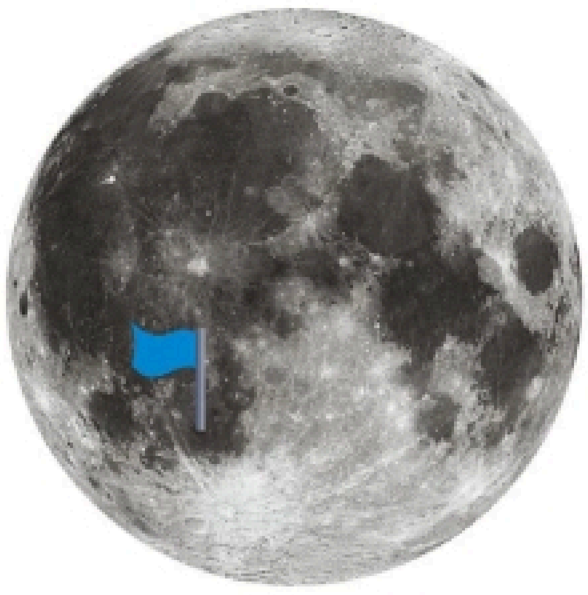
Wolf

Finding this lunar crater won't leave you howling with frustration on cold January nights

Many people don't realise that the full Moons seen throughout the 12 calendar months have names, often rooted in nature. These can be traced back to before the Julian calendar was followed and have ties to the Native Americans. For example, May's full Moon is the 'Flower Moon'. In November the 'Hunter's Moon' shines over our Bonfire Night celebrations and as December ends late-night Christmas shoppers scurry around looking for last-minute gifts beneath the 'Cold Moon'.

This January, the full Moon that will illuminate our frosty grass and windscreens and the snowmen slumping in our gardens is known as the 'Wolf Moon', named by Native Americans after the mournful howling of hungry wolves searching for food halfway through winter. Obviously wolves are in quite short supply in the UK these days, but there is one place you can guarantee seeing one this month – on the Moon itself. Our Moon Tour destination for January is the small crater 'Wolf'.

Named after the accomplished German astronomer Max Wolf – who discovered several comets and supernovae, proved dark nebulae were clouds of interstellar dust and discovered no fewer than 248 asteroids in his lifetime – Wolf crater is 26 kilometres (16 miles) wide and not quite a kilometre deep, making it one of the smaller craters we've visited on our long tour. It lies almost in the centre of Mare Nubium, the 'sea of clouds', a roughly circular dark stain on the Moon which can be found to the southeast of the much larger Oceanus Procellarum. The crater was photographed by the crew of Apollo 16 in 1972, which landed in the Descartes Highlands region, and was imaged again more recently, but in much higher resolution, by the Lunar Reconnaissance Orbiter's cameras.



Although it is small itself, Wolf can be found quite easily because it lies halfway between two larger, more obvious craters: Bullialdus to its upper left and Pitatus to its lower right. Far too small to be seen with the naked eye and a challenge with a pair of binoculars, Wolf sadly looks nothing like a wolf. Through a telescope's low-power eyepiece it appears as a roughly heart-shaped feature. Higher magnifications reveal a gap in Wolf's southern rim which makes it look more like a small vase or the Greek 'Omega' symbol than a heart.

Wolf's walls are relatively featureless, thicker and wider in some places than others, and its floor is dark and flat with a short, curved chain of four small secondary craters on its western side. The most remarkable thing about Wolf is probably the bright apron of ejecta that spreads out from its sides and bottom, like an open cloak. Look at that through your telescope's highest magnification eyepiece and you'll see it is very rugged and hummocky, spattered with its own small craters. It looks like a small part of the lunar highlands surrounding the crater.

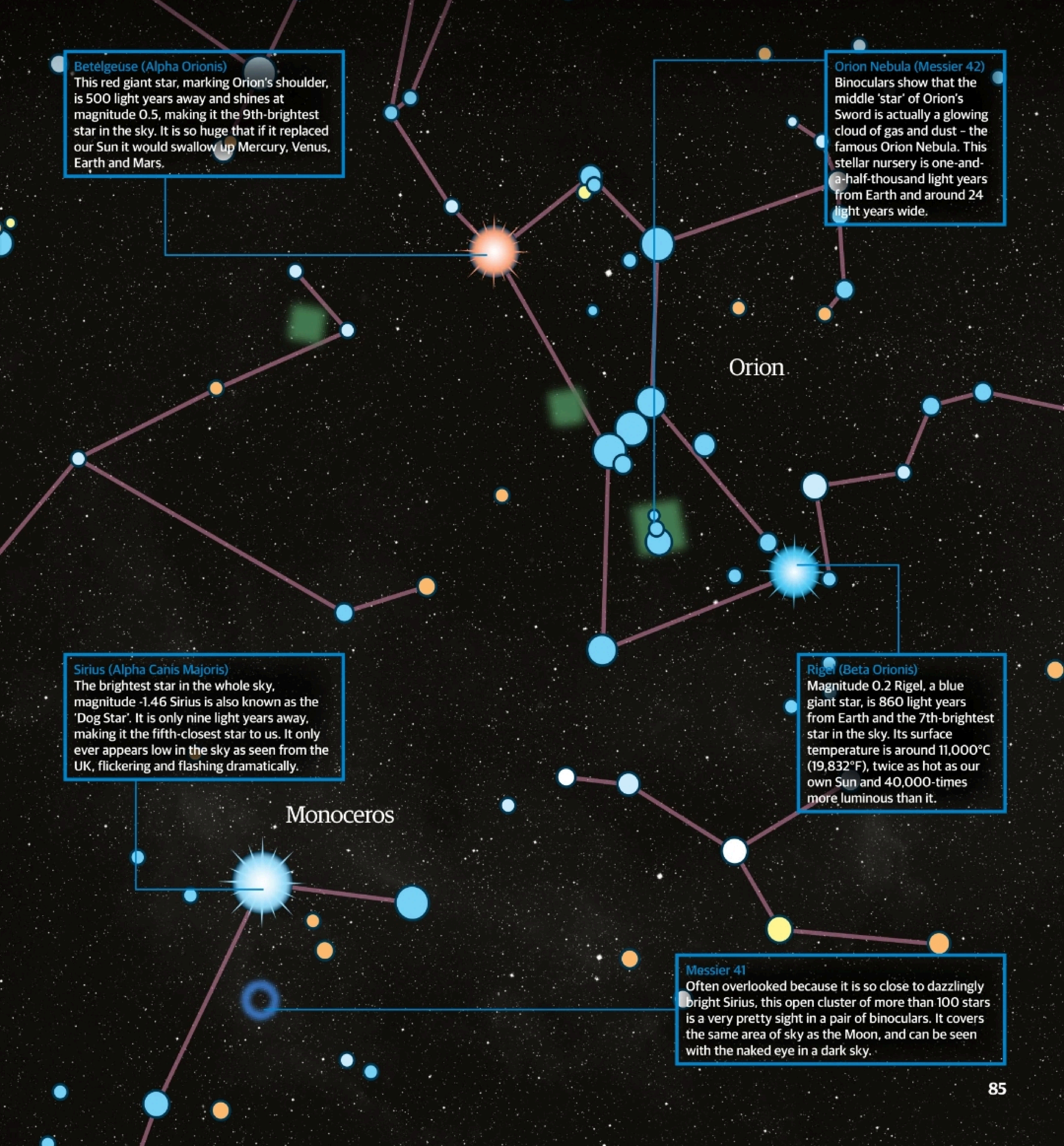
So when can you see this crater for yourself? At the start of our observing period Wolf is not visible, totally hidden in shadow. However, by the evening of 4 January the terminator will have swept over the crater like a dark tsunami and Wolf will be illuminated from the east. This will be a good time to look for details and small features on its floor and that surrounding ejecta apron, as they are lit by the slanting rays of the low Sun. Wolf will remain fully illuminated between 4 and 18 January, but by the 19th the terminator will have rolled over it again and it will have vanished, not to reappear until next month.

While Wolf might not be the most striking or dramatic crater on the Moon, it is definitely worth a look at through your telescope. It's a valuable reminder that the Moon has a lot more to offer the observer than the 'celebrity' features like Copernicus, Tycho and the Sea of Tranquillity.

© NASA

Naked eye & binocular targets

Crisp January nights offer observers glittering clusters, misty nebulae and giant stars that dwarf our own Sun



Betelgeuse (Alpha Orionis)
This red giant star, marking Orion's shoulder, is 500 light years away and shines at magnitude 0.5, making it the 9th-brightest star in the sky. It is so huge that if it replaced our Sun it would swallow up Mercury, Venus, Earth and Mars.

Orion Nebula (Messier 42)
Binoculars show that the middle 'star' of Orion's Sword is actually a glowing cloud of gas and dust – the famous Orion Nebula. This stellar nursery is one-and-a-half-thousand light years from Earth and around 24 light years wide.

Sirius (Alpha Canis Majoris)
The brightest star in the whole sky, magnitude -1.46 Sirius is also known as the 'Dog Star'. It is only nine light years away, making it the fifth-closest star to us. It only ever appears low in the sky as seen from the UK, flickering and flashing dramatically.

Rigel (Beta Orionis)
Magnitude 0.2 Rigel, a blue giant star, is 860 light years from Earth and the 7th-brightest star in the sky. Its surface temperature is around 11,000°C (19,832°F), twice as hot as our own Sun and 40,000-times more luminous than it.

Messier 41
Often overlooked because it is so close to dazzlingly bright Sirius, this open cluster of more than 100 stars is a very pretty sight in a pair of binoculars. It covers the same area of sky as the Moon, and can be seen with the naked eye in a dark sky.

Deep sky challenge

Scan the skies beyond Orion

Track down some of winter's lesser-known wonders on the next clear and frosty night...

As you set up your telescope on freezing cold January nights, with the grass crackling and snapping beneath your feet and your breath forming glittering silvery clouds in the air around your face, it's always tempting to look at the same things you always do – the misty, swirling veils of the Orion Nebula, the 'mini-Dipper' Pleiades cluster with its stars sparkling like jewels and the Crab Nebula's ghostly haze all call out to you through your favourite eyepiece. But there is much more to the winter sky than those 'celebrity' objects, and if you swing your ice-cold telescope tube towards the constellation of Gemini, put in a high-power eyepiece and go deep, you can see some lesser-known objects that deserve your attention just as much as their more famous neighbours.

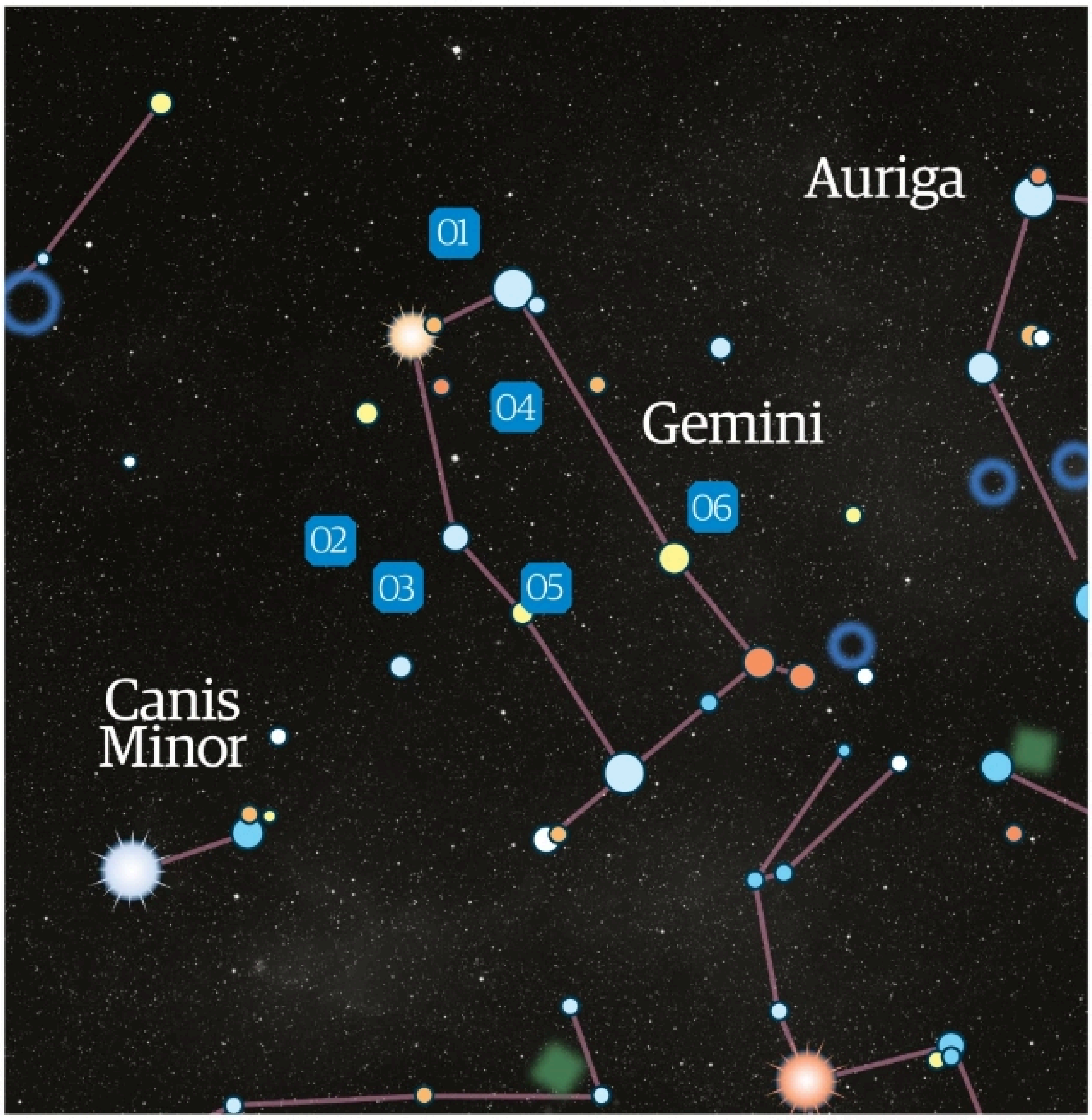
Gemini is dominated by the beautiful open cluster M35, one of winter's showcase objects, and it's a beautiful sight in anything from a humble pair of binoculars to a cannon-sized Dobsonian. But scattered around it are much fainter, much more distant objects that are real treats once tracked down. The 'Eskimo Nebula' – sometimes known as the 'Clownface Nebula' – is a lovely, intriguing planetary nebula that shows fascinating detail and structure through a large telescope; the 'Twinkling Comet Cluster' is a very pretty object, and NGC 2324 is a spiral galaxy more than 250 million light years away.

Orion Nebula (M42)

© ESO

Source: Wiki ©Sloan Digital Sky Survey

Source: Wiki ©Judy Schmidt



© Wil Tirion

1 NGC 2435

This spiral galaxy, almost edge-on to us, is 200 million light years away. Measuring just 15 arc minutes across and shining at 13th magnitude, it is a challenge in even a large telescope.

2 Twinkling Comet Cluster (NGC 2420)

This 8th-magnitude cluster actually looks nothing like a comet; it is similar to M44, the Beehive Cluster – a loose spray of stars in the centre of a keystone of four brighter stars.

3 The Eskimo Nebula (NGC 2392)

In a large telescope's high-power eyepiece this 9th-magnitude planetary nebula really does look like a face surrounded by a hood. Under a dark sky you'll be able to see mottling within it.

4 NGC 2331

4,000 light years from Earth, this sparse open cluster is 8th magnitude and a telescope's medium-power eyepiece will show it as a loose, irregular clump of around 30 suns.

5 NGC 2324

You'll need a large telescope, dark skies and high magnification to see this 12th-magnitude galaxy. Under perfect conditions you will see hints of its tightly wound spiral arms.

6 NGC 2266

Dominated by a chain of bright stars that cuts across its centre like a mini Orion's Belt, this roughly triangular magnitude 9.5 cluster is a real treat in medium and large telescopes.

The Northern Hemisphere

The New Year has arrived with some of the very best night-sky targets, studded in long winter nights

Whether you just got your first telescope for Christmas or you've long been observing, there are some wonderful targets to seek out in the New Year.

Orion (the Hunter) and Taurus (the Bull) remain prominent in the sky, offering splendid sights including red supergiant Betelgeuse, brilliant blue-white Rigel, the Pleiades star cluster (Messier 45), orange giant Aldebaran and, of course, the Crab Nebula (Messier 1). Look southeast and you'll spot a celestial Great Dog: a seemingly basic-looking pattern of stars, Canis Major features several binary systems and supergiant stars. It's also home to open cluster Messier 41, which contains an impressive collection of red giants and white dwarfs, not too far from 'Dog Star' Sirius.

Using the sky chart

This chart is for use at 22:00 (GMT) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

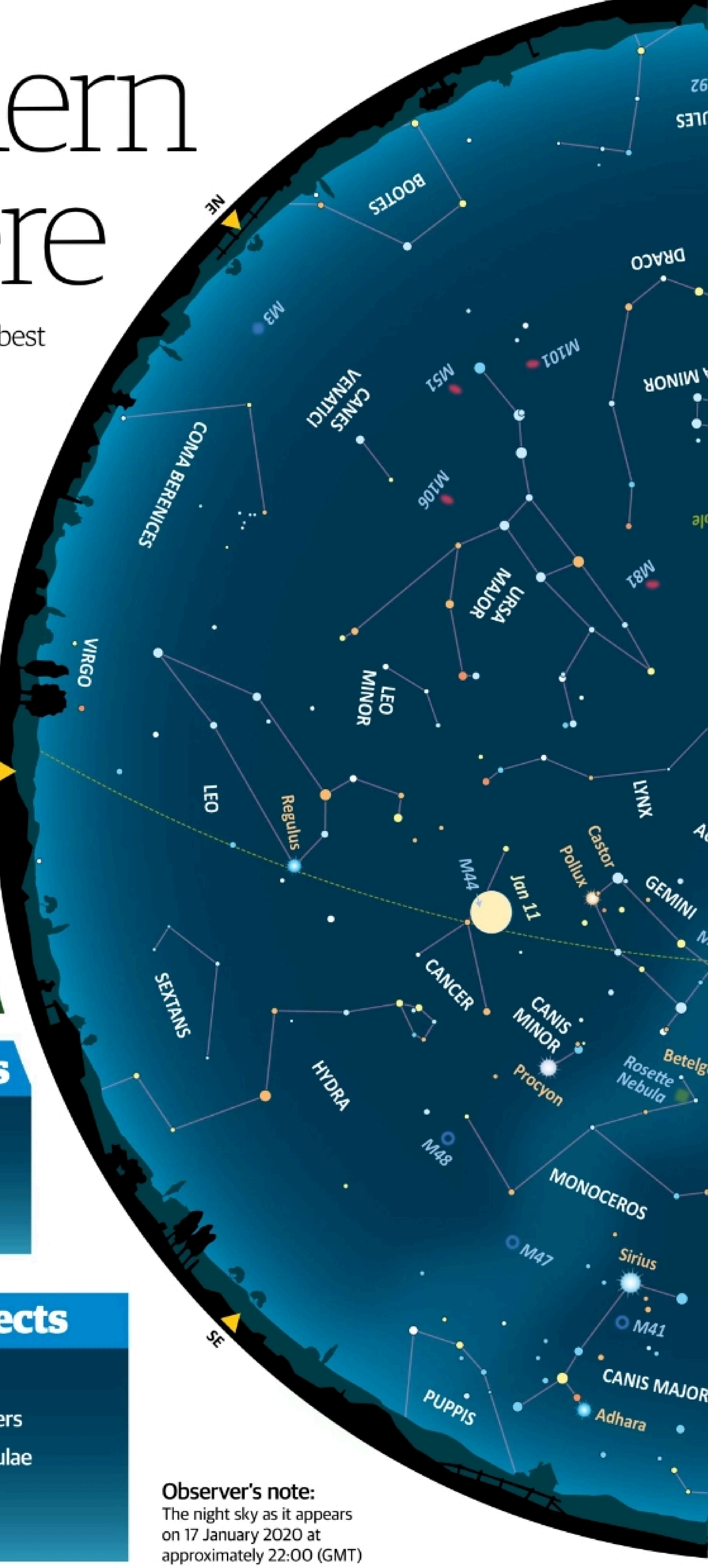
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

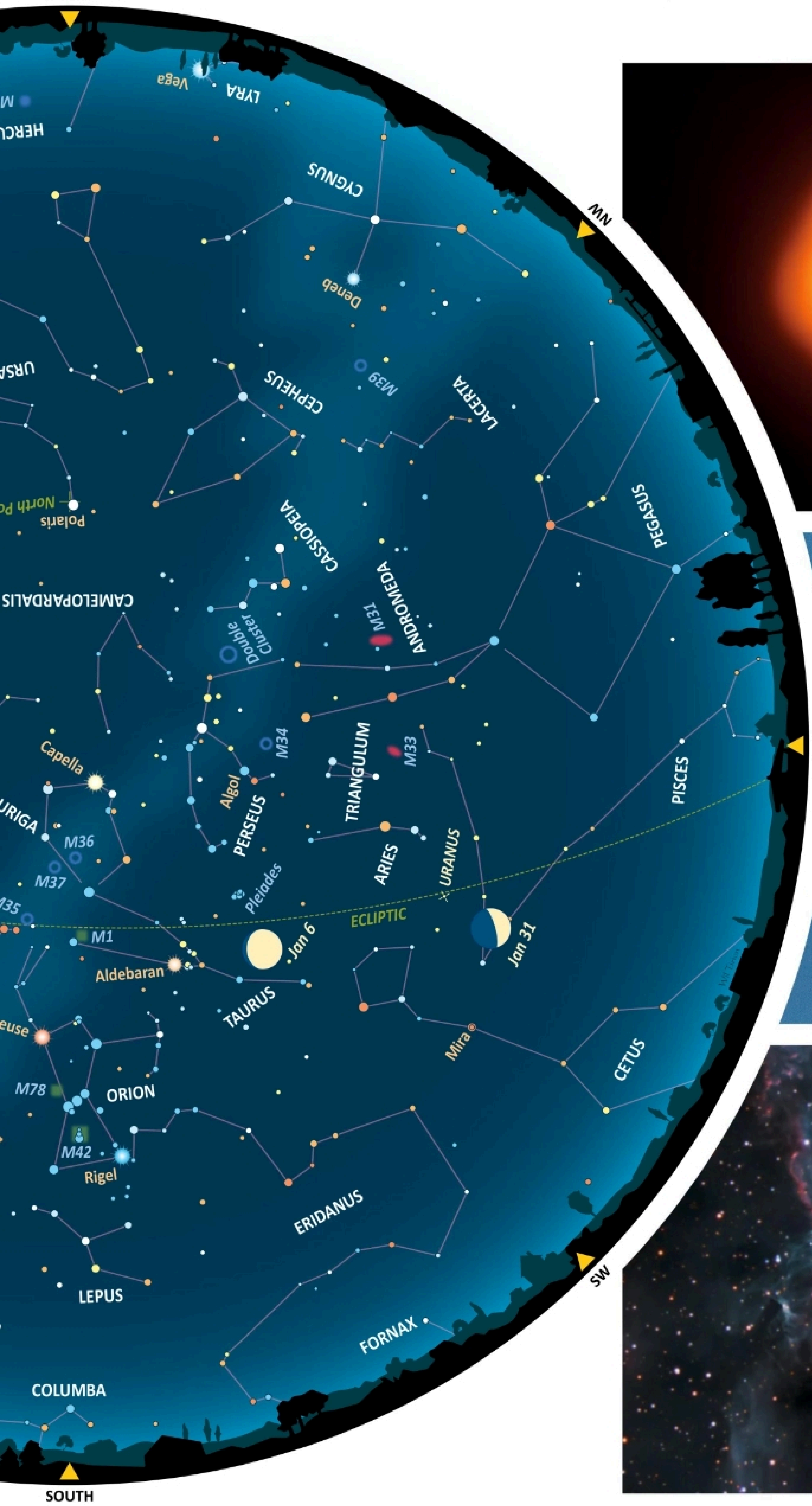
- ● O-B
- ● A
- ● F
- ● G
- ● K
- ● M

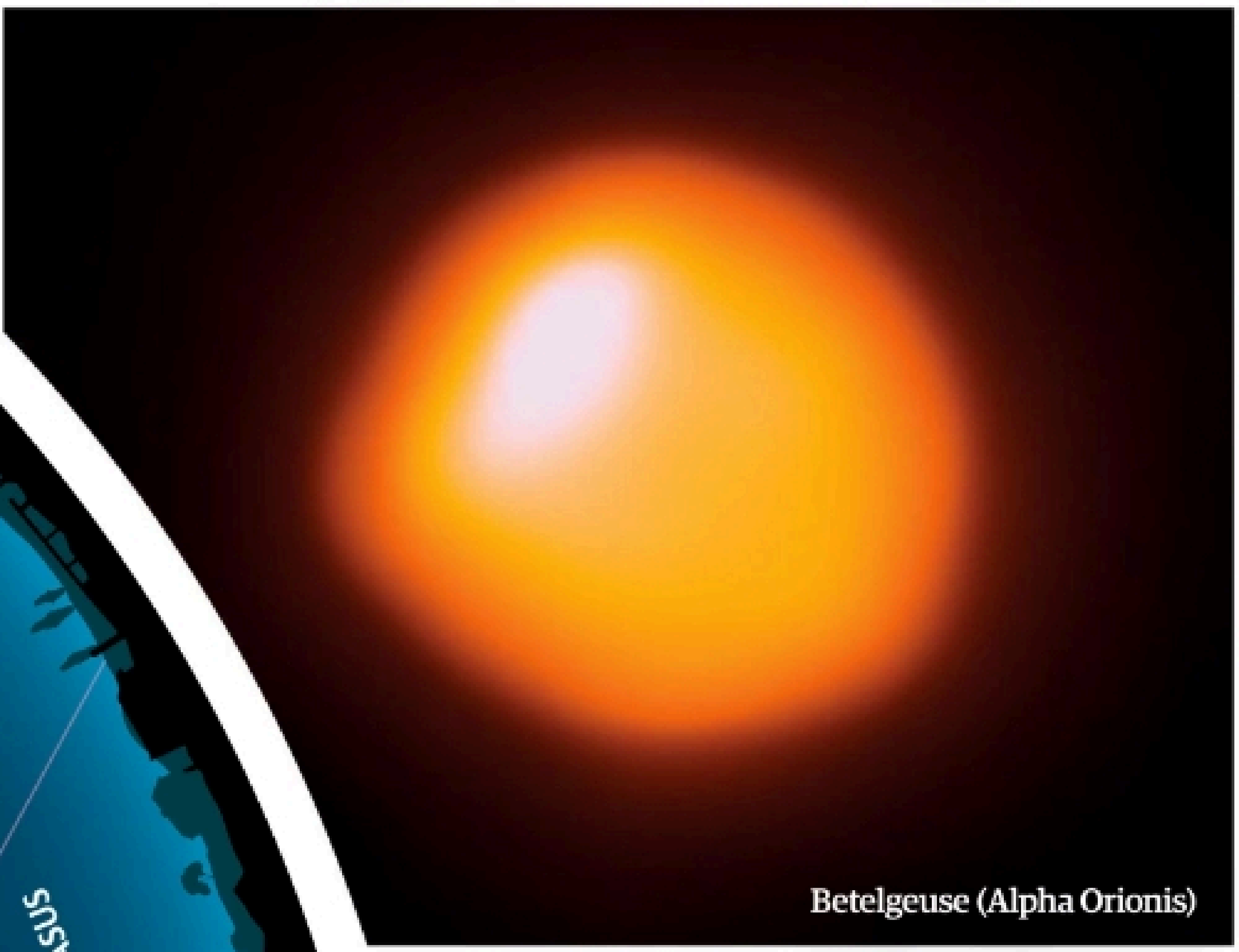
Deep-sky objects

- ○ Open star clusters
- ● Globular star clusters
- 🟩 Bright diffuse nebulae
- ○ Planetary nebulae
- ● Galaxies



Observer's note:
The night sky as it appears on 17 January 2020 at approximately 22:00 (GMT)




Betelgeuse (Alpha Orionis)

Source: Wiki © ALMA

Waxing gibbous Moon

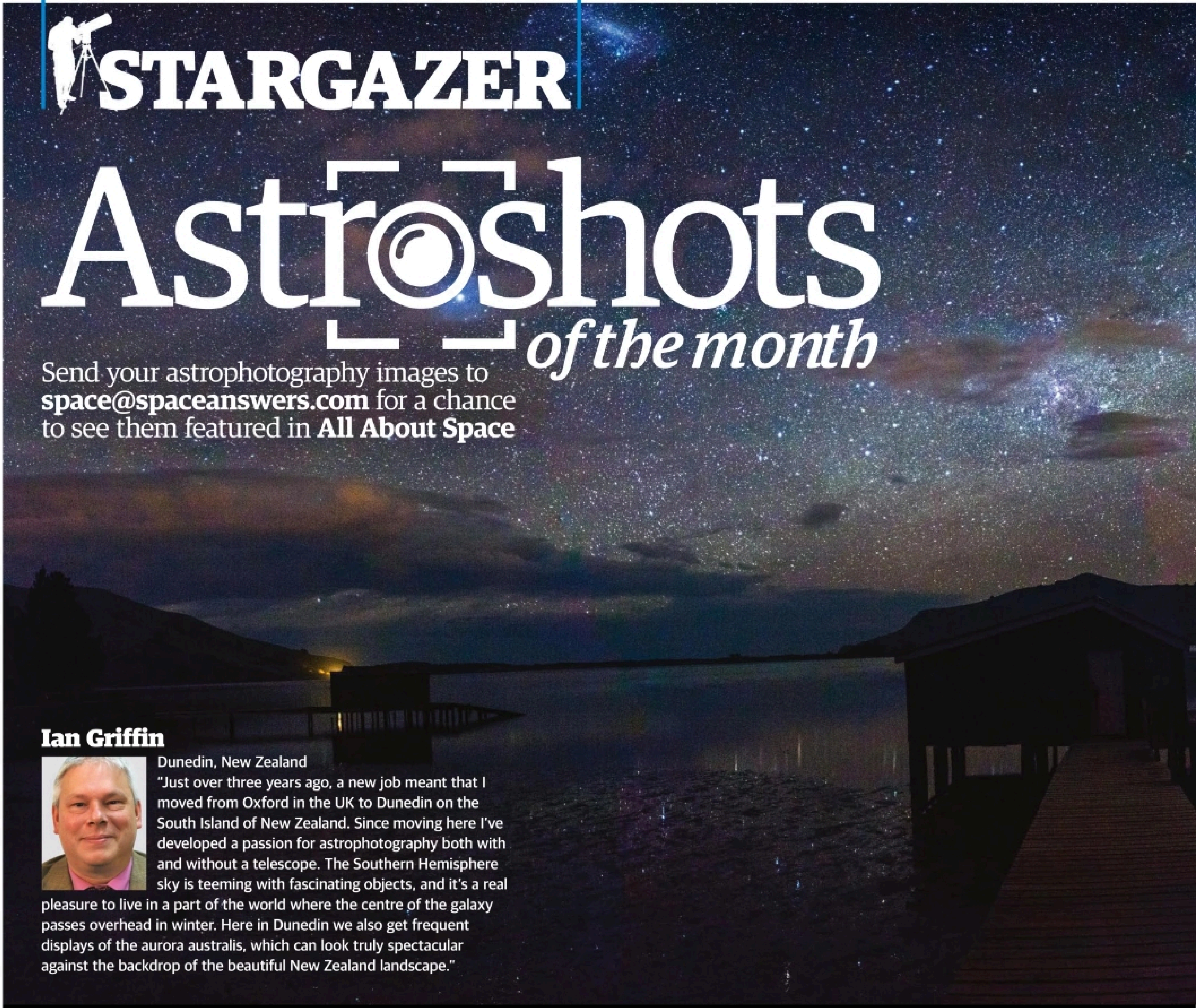
Source: Wiki © FiLA

Thor's Helmet (NGC 2359)

Source: Wiki © CXIELO

Astroshots of the month

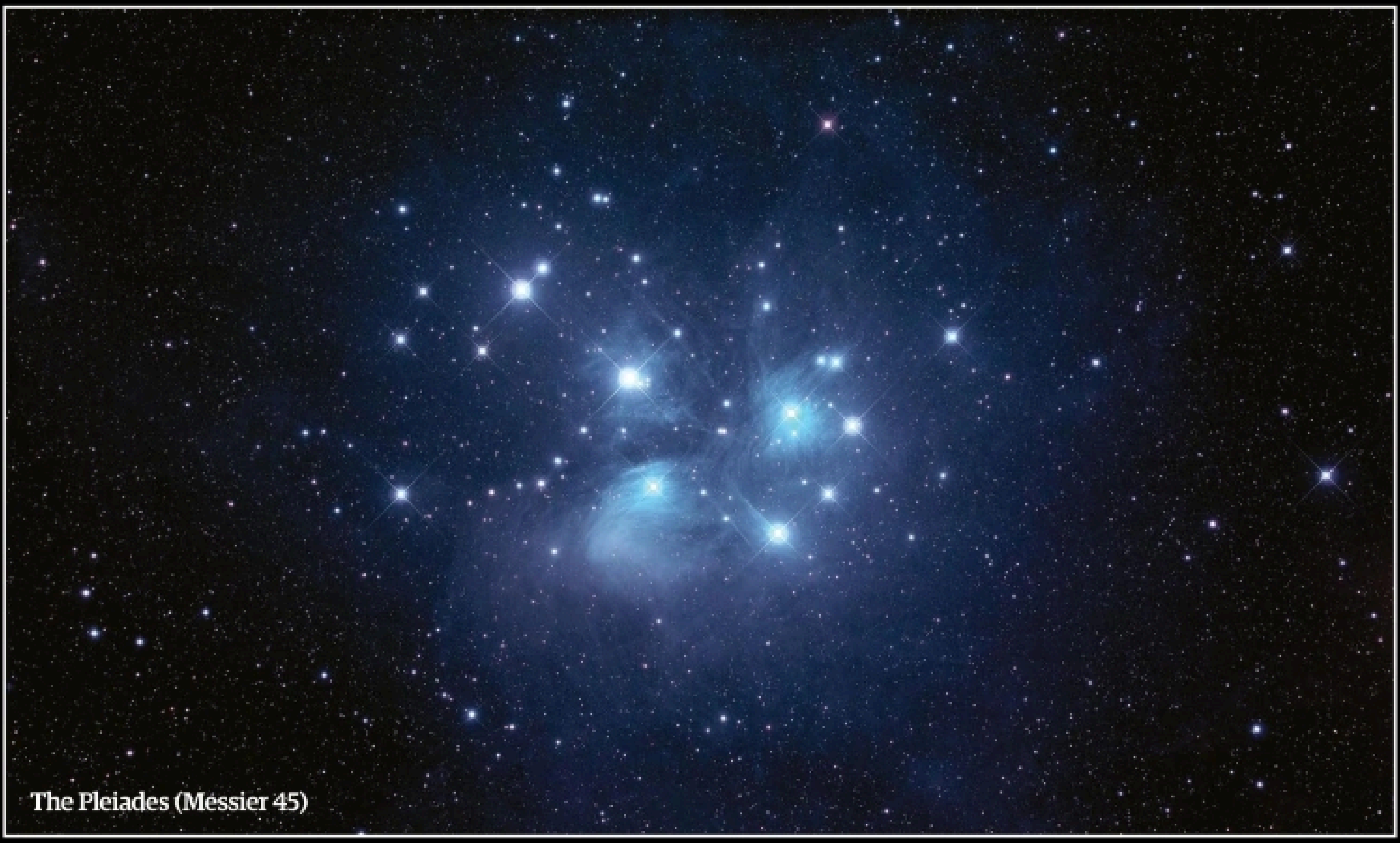
Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**



Ian Griffin

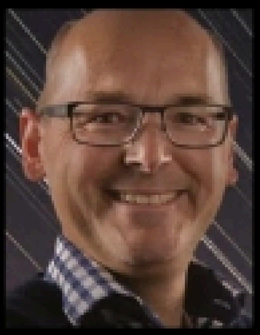
Dunedin, New Zealand

"Just over three years ago, a new job meant that I moved from Oxford in the UK to Dunedin on the South Island of New Zealand. Since moving here I've developed a passion for astrophotography both with and without a telescope. The Southern Hemisphere sky is teeming with fascinating objects, and it's a real pleasure to live in a part of the world where the centre of the galaxy passes overhead in winter. Here in Dunedin we also get frequent displays of the aurora australis, which can look truly spectacular against the backdrop of the beautiful New Zealand landscape."



The Pleiades (Messier 45)

Ullrich Dittler



Black Forest, Germany

Telescope: Takahashi FSQ-106 and Celestron C11

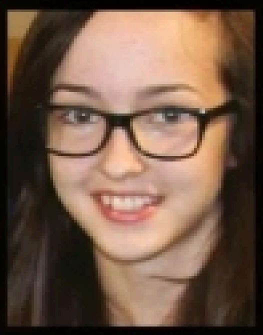
"Even as a child I was interested in astrophotography, but during my studies and my first few years of work I never had the chance to image, as I lived in a light-polluted city. Now I live in a small town under a dark sky, and have done for a few years. The observation conditions are so good that we have built an observatory in the garden. I like to photograph the daily changing view of the Sun in white light, in H-alpha light and calcium light. I also like to take pictures of deep-sky objects to image structures that humans are unable to see."

> "The Southern Hemisphere sky is teeming with fascinating objects"

The Milky Way from the Southern Hemisphere

A waxing gibbous Moon showing craters and mare

Katherine Ormerod



Chorley, Lancashire

Telescope: Celestron NexStar 5SE

"I began to have an interest in space around six years ago. It wasn't until quite recently that I developed a strong passion for observing. I have always been interested in science, particularly physics, which later led me to buy a telescope with the aim of viewing the Solar System and the Moon. I find the lunar surface very interesting because of the incredible detail that you can see with low magnification."

Send your photos to... @spaceanswers space@spaceanswers.com

Celestron Cometron FirstScope 76

Designed with the beginner or casual astronomer in mind, this tabletop telescope is compact, portable and provides good night-sky views

Telescope advice

Cost: £72/$90.75
From: David Hinds Ltd
Type: Reflector
Aperture: 76mm (2.99")
Focal length: 300mm (12")

Best for...

- Beginners and Intermediate
- Small budgets
- Planetary viewing
- Lunar viewing
- Deep-sky objects

There are several things that novice sky-watchers crave when choosing their very first telescope: portability, ease of use and a price that's not going to break the bank. We're pleased to say that the Celestron Cometron FirstScope ticks all of the boxes. What's more, this tabletop telescope comes with all of the accessories you need for any beginner wanting a fuss-free tour of the night sky, providing much improved and more comfortable views of the planets and lunar surface over the naked eye or even binoculars.

When unpacking the FirstScope, you'll notice that it is already preassembled, with only the 5x24 finderscope needing to be affixed to the telescope tube. The FirstScope is supplied with two Kellner eyepieces - a 10mm and a 20mm - and possesses a fast focal ratio to provide a wide field of view that's ideal for viewing the planets and the lunar surface, but also allows the user to view wide-angle star clusters.

Weighing in at a mere 1.95 kilograms, the FirstScope is ideal for those looking for a grab-and-go instrument. On close inspection of the overall build, the finish isn't perfect, with traces of glue apparent on the tube. Considering what you get for the price though, the scope's plastics aren't glossy and cheap. You'll notice that the telescope's base is short, meaning that you'll need to place it on a table for comfortable use. On the plus side though, if you have children who have been pestering you for a telescope, the Cometron FirstScope is the perfect solution, especially given the low price and ease of use.

With Newtonian designs, the two mirrors within the tube should be aligned. Astronomers usually achieve this process - known as collimation - using thumbscrews to adjust the optical system. Unfortunately these aids are only usually on the more expensive models, meaning that it was quite a task trying to collimate the Cometron FirstScope, as the primary mirror isn't adjustable and a collimation cap or eyepiece isn't actually included with the telescope.

Early December provided a gaggle of Solar System targets including Mars, Venus, Saturn and the Moon to test the telescope's optical system. Our lunar companion was at 22 per cent illumination, meaning that there wasn't too much natural light pollution to hinder our views of other targets we were keen to observe. With the eyepieces supplied, you won't get hugely close-up views of the surface of the Moon, but you'll be able to see craters and get a feel for the rugged terrain along the terminator.

Views aren't hugely pin-sharp through the field of view, since the focuser tube is quite loose, but they are sure to delight those who have always wanted to get a closer look at the lunar surface without straining their eyes. With Venus in the southwest and shining at a stunning magnitude of -4.9, we turned the scope to the second planet from the Sun. As expected, we didn't see a great deal of detail, but were treated to a white disc of a bright-white 'star'. Meanwhile, the Cometron's wide-angle views provided fair sights of the Pleiades star cluster, also known as Messier 45, in the constellation of Taurus. Each of the young, hot member stars in this open cluster were exquisite through the field of view. Using the finderscope did prove quite cumbersome during our observations though, making star-hopping quite difficult in light-polluted areas - for instance, it failed to pick up stars with magnitudes below naked-eye visibility - so it makes more sense to use a red-dot finder for simpler navigation.

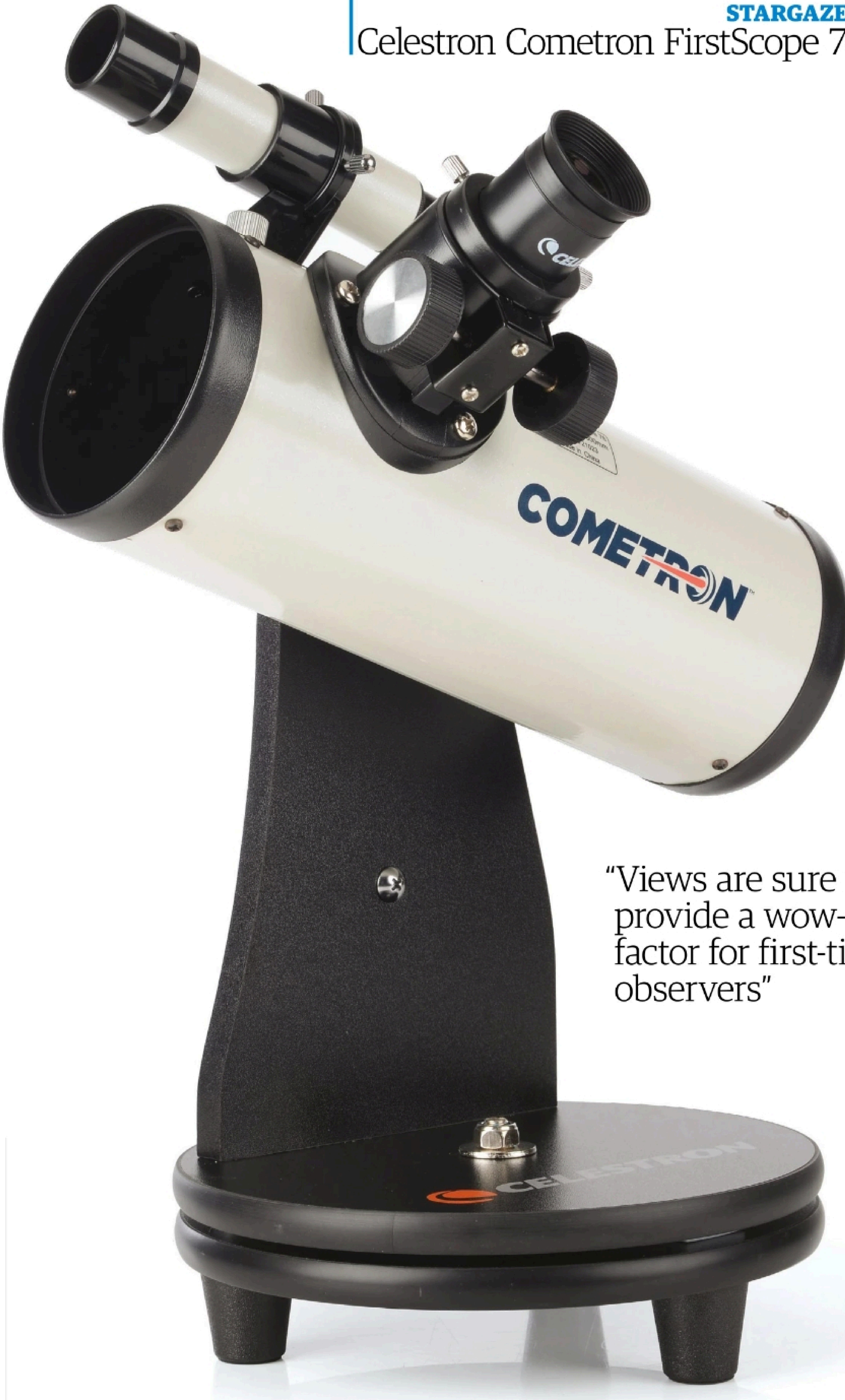
Waiting until dawn was worthwhile as Jupiter, which shone at -1.9, rose in the southeast. While it was difficult to spot any details on the gas giant, such as its belts and Great Red Spot, the Galilean moons - Io, Ganymede, Europa and Callisto - appeared as bright spots either side of the king of the Solar System's limbs. While the views aren't as good as you'd expect through a more dedicated scope, they are sure to provide a wow-factor for first-time observers.

If you're looking for a fuss-free piece of equipment to compliment your existing telescope, we recommend a pair of binoculars. However, if you have children who have been bugging you for a telescope and you can't quite commit to a moderately priced instrument, then the Cometron FirstScope may be for you - especially if the lunar surface, the planets and casual glances at the night sky are of interest.

Left: An alt-azimuth design is employed, allowing for simple use so that you can skip setting up and get observing

Left top: The FirstScope comes supplied with 10mm and 20mm eyepieces

Right: The 5x24 finderscope should be replaced with a red-dot finder for easy navigation



"Views are sure to provide a wow-factor for first-time observers"

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If climbing Scafell Pike – the tallest mountain in England – isn't for you when it comes to getting closer to the heavens, then never fear; you can simply stick close to your cabin and catch everything from those tricky-to-see galaxies to firm favourites of the Solar System. If you prefer an easy gaze without a telescope, then the Milky Way in all its majesty is on show up until spring.

There are plenty of opportunities to explore the surrounding area while you're waiting for it to get dark: rolling countryside and rugged mountainous terrain surrounds you, while a hot tub gives you the perfect opportunity to relax.

Winner must respond within seven days or the prize will be forfeited and another winner will be chosen. Qualifies for a three-night stay (Friday to Monday) for two adults at either Pelton Wheel Cottage or Millrace Cottage. Pets are welcome. Prize must be taken before 23 March 2020 and excludes school holidays. Travel costs not included.

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To be in with a chance of winning, all you have to do is answer this question:

Messier 101 is another name for which celestial object?

A: The Pinwheel Galaxy

B: The Orion Nebula

C: The Cartwheel Galaxy

Competition ends on 30 January 2020

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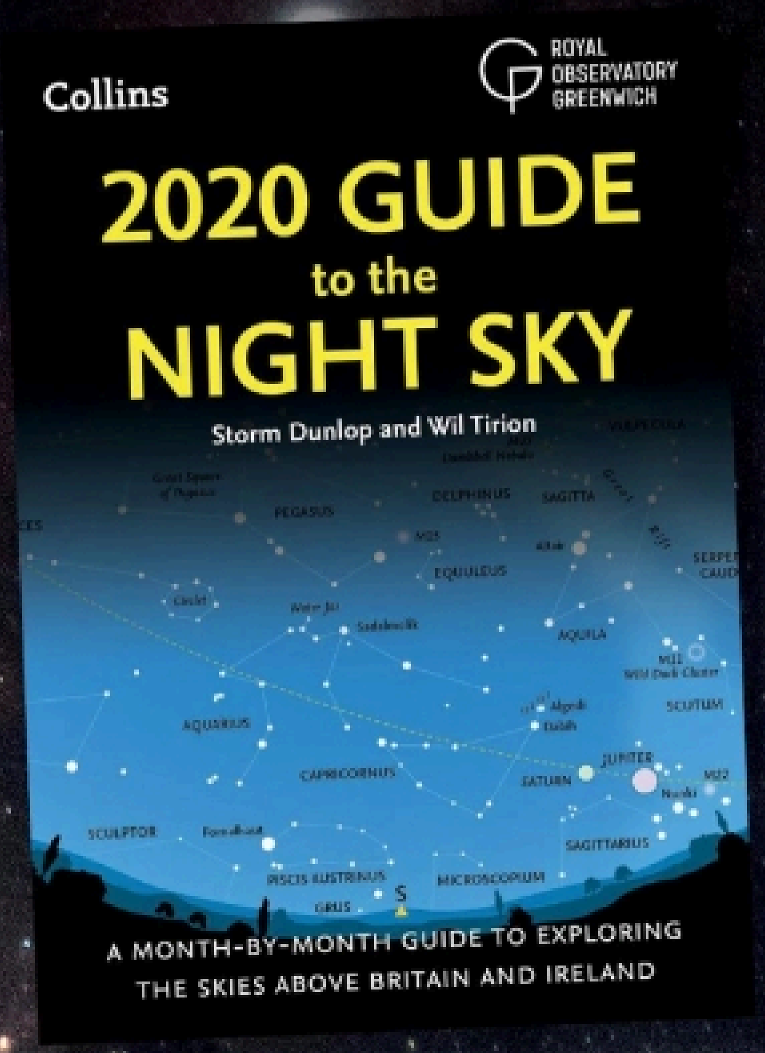
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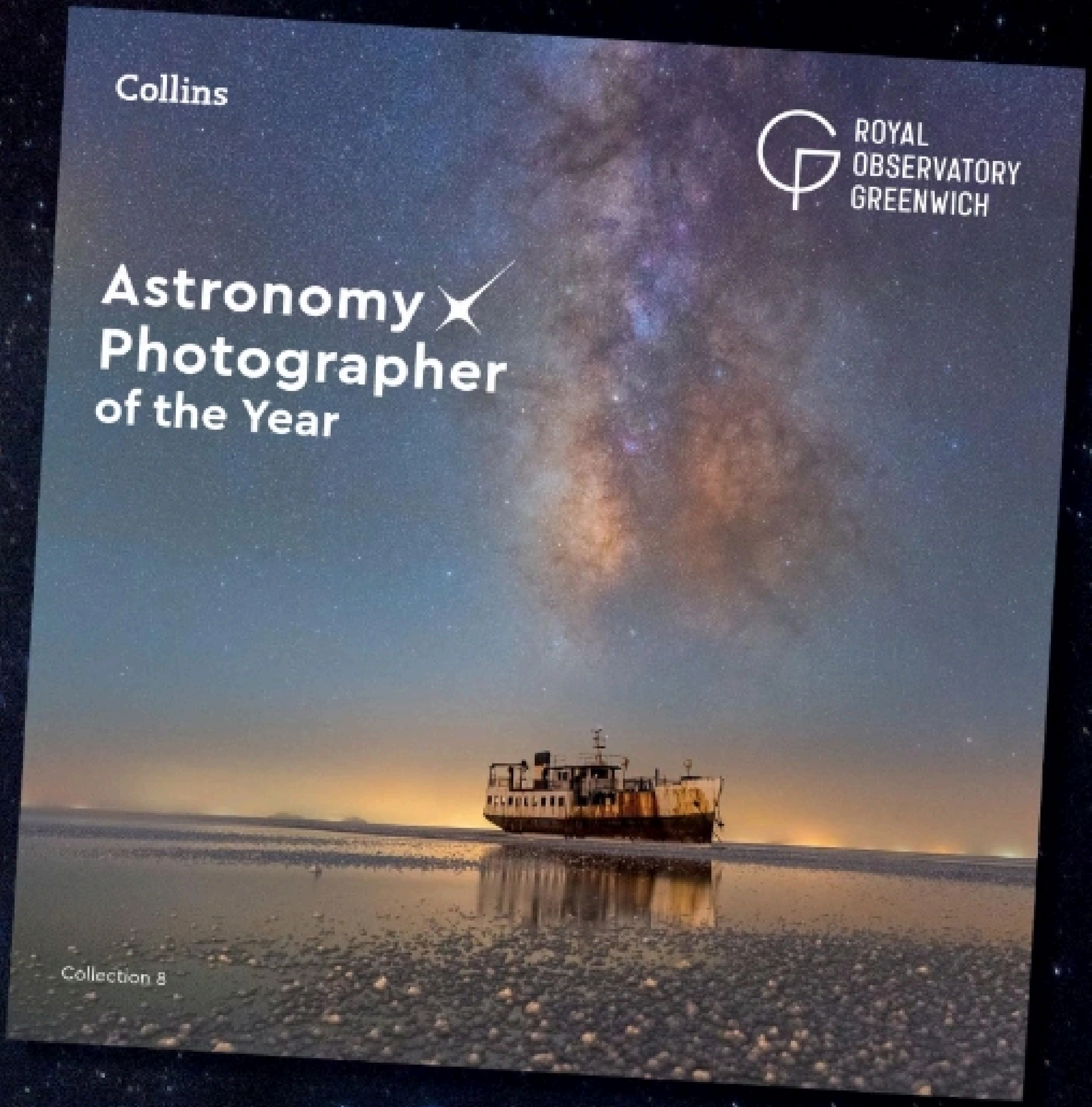
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Book

Astronomy Photographer of the Year 2019

Cost: £25.00/$39.95

From: Royal Observatory Greenwich

Be captivated by 140 winning and shortlisted images from the 2019 Insight Investment Astronomy Photographer of the Year competition. A showcase of the most spectacular space photography of its kind, the hardback book is adorned with breathtaking images taken from locations across the globe. Marvel at the wonders of the universe captured by the most talented astrophotographers, also on display at the National Maritime Museum now.

These awe-inspiring images were submitted in several categories: aurorae, skyscapes, people and space, our Sun, our Moon, planets, comets and asteroids, stars and nebulae, galaxies and a young competitor category, with each image accompanied with a caption that provides everything you need to know from the location, tips from the astrophotographer on capturing such a stunning shot and technical details.

App

Luminos 9.6.2

Cost: £7.99/$9.99

From: iTunes

Luminos has all of the workings of an excellent app, allowing you to point and scan as well as identify objects. The app does have some extras over other night-sky apps that many users will certainly appreciate. This includes a feature that allows you to mark targets as you find them in the night sky, also recording the date and allowing you to add some observer's notes.

Over other apps that we've used, there is a lot more in the way of objects – including asteroids and satellites – among others in the catalogue. A feature that we enjoyed in particular was being able to 'hitch a ride' on a satellite, which allows you to observe countries from orbit. You can also choose to observe from another world or object in the Solar System.

If you own a telescope or pair of binoculars, you can set the field of view, which makes star hopping and locating objects easy – a useful function that gets a massive thumbs up from us!

Watch
Shepherd Watch

Cost: £500.00 (approx. $658.85)
From: Royal Observatory Greenwich
With a design that's based on the world-famous 24-hour Shepherd Gate Clock – Britain's time system, which was originally located at the gates of the Royal Observatory and meridian line and the first to show Greenwich Mean Time (GMT) – this stunning timekeeper features an Italian leather watch strap, sapphire-coated mineral crystal face, mineral glass caseback window and wooden presentation box, silicon black strap, nylon strap, cloth and operating instructions.

The watch's minute and second hands are conventional, while the hour hand makes one revolution round the dial once in 24 hours. At midday the minute hand points to the top, while the hour hand points down on a black-and-white dial etched in Roman numerals, set in a black stainless steel bezel with black crown. A stunning gift for a loved one or yourself.

> "This stunning timekeeper features an Italian leather watch strap"

Accessories
Philip's Moon Map

Cost: £6.99 (approx. $9.20)
From: Philip's Astronomy
If you're a keen lunar observer, then this beautifully illustrated Philip's Moon Map is one of the most detailed lunar guides on the market. Over 500 craters, mares, mountain ranges, peaks, valleys and rilles are labelled, ensuring that you can plan and identify features during your observations of the nearside of our natural satellite with ease. Philip's Moon Map is reasonably priced – especially if you're keen to explore the lunar surface as closely as possible. It also includes details on the phases along with details on its orbit around our planet.

Using the map has its challenges – being so large, it catches even the slightest of breezes, making it difficult to use. We recommend pinning it down to a garden table using paperweights, which will allow for hands-free use. Additionally, being made of paper, it's unable to withstand the elements sufficiently, which could lead to tearing and damage from moisture and general use. Under red light, the map can be read with ease – an important attribute for those wanting to use it during their observations without ruining their night vision.

PHILIP'S
MOON MAP
DETAILED MAP OF THE MOON'S VISIBLE SURFACE
500 MOON FEATURES LOCATED, WITH INDEX
CRATERS, SEAS, MOUNTAINS, PEAKS AND VALLEYS
LANDING SITES OF MANNED AND UNMANNED SPACECRAFT LOCATED
NEW EDITION

HEROES OF SPACE

Edgar Mitchell

He was one of the 12 lucky astronauts to ever touch down on Earth's natural satellite, the Moon

Mitchell's one and only spaceflight was on Apollo 14

© NASA

Edgar Mitchell was the sixth person to ever step foot on the surface of the Moon as part of the Apollo 14 mission, exploring the Fra Mauro highlands along with commander Alan Shepard on 5 February 1971. This feat pushed the boundaries of human exploration at the time, with the pair spending more than 33 hours on the Moon, this including the nine-and-a-half hours they spent conducting extravehicular activities (EVAs).

Mitchell was born on 17 September 1930 in Hereford, Texas. His early years would later help him in becoming an astronaut: he was well-educated, graduating with a doctorate in aeronautics and astronautics from the Massachusetts Institute of Technology (MIT) in 1964, as well as being a US Navy member with aviation experience.

Mitchell recalled in a 1997 interview for NASA's oral history project that it was President Kennedy's famous speech in 1962 that made him become an astronaut: "After Kennedy announced the Moon programme, that's what I wanted, because it was the bear going over the mountain to see what he could see, and what could you learn, and I've been devoted to that, to exploration, education and discovery since my earliest years, and that's what kept me going."

Mitchell was selected as an astronaut in 1966. His earlier involvements include being part of the support crew for Apollo 9 and backup Lunar Module pilot for Apollo 10. He also developed vital procedures at Johnson Space Center that would save the Apollo 13 crew from potential disaster. However, it was Apollo 14 that brought Mitchell's one and only trip to space.

> "Mitchell recalled in a 1997 interview that it was Kennedy's famous speech that made him become an astronaut"

Along with commander Alan Shepard and Command Module pilot Stuart Roosa, Mitchell assumed the duties of the Lunar Module pilot, spending over a day on the Moon's surface and making history. This mission saw Shepard and Mitchell set records at the time, including the longest distance travelled on the lunar surface, the largest payload delivered and the longest lunar stay. They were also the first astronauts to transmit colour television back to watchers on Earth. They returned with 43 kilograms (94 pounds) of lunar rock for further analysis.

This mission sparked a spiritual awakening within Mitchell, and this led to him pursuing more unorthodox research interests after his career with NASA and the US Navy. You may be thinking, what could be more unorthodox than going to the Moon? Well, Mitchell's interests soon turned to parapsychology – the study of inexplicable phenomena – with him conducting research into UFOs, telepathy and so on. He co-founded the Institute of Noetic Sciences in 1973, and as his second wife Anita Mitchell recalled, in the process of this she had "met all the nuts, flakes and fruits in the whole granola box."

Mitchell passed away at West Palm Beach in Florida on 4 February 2016, some 45 years after flying on the Apollo 14 mission, and although his latter pursuits were largely deemed unusual, his efforts in space exploration and his motivation to explore beyond humanity's confines is something to be greatly commended.

All About Space

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Printed by William Gibbons & Sons Limited, 26 Planetary Road, Willenhall, Wolverhampton, West Midlands, WV13 3XB

Distributed by Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU www.marketforce.co.uk Tel: 0203 787 9060

ISSN 2050-0548

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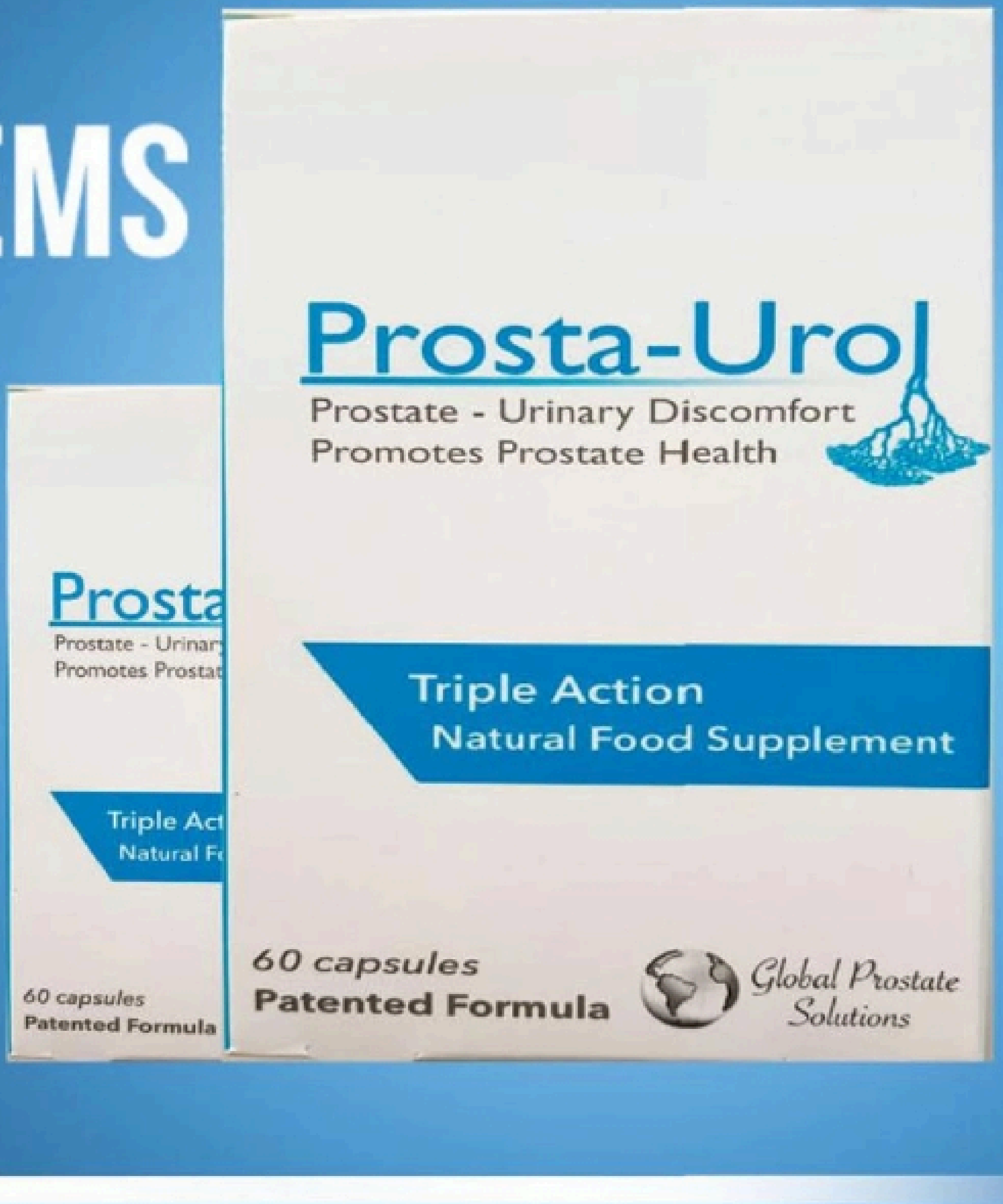

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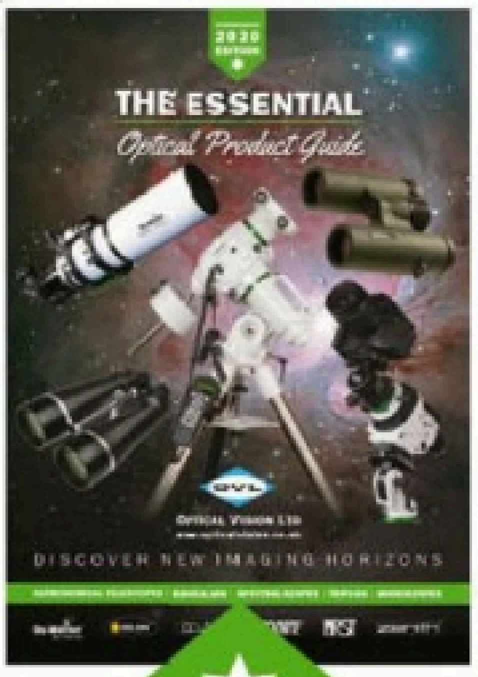

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